Innovation and Entry Deterrence in an Open Access Network

Kay Mitusch* — *TU Berlin*
Andreas Brenck — *TU Berlin*

1st March 2004

Abstract

Systemic innovations play a crucial role for the development and efficiency of network industries. This paper centers on the incentives of an incumbent to innovate. Two problems are highlighted: Entrants may benefit from systemic innovations without sharing the burden of innovation costs; at the same time, systemic innovations often raise entrants' costs, resulting in a lower probability of entry. The simultaneous existence of these two aspects allows the incumbent to tailor his innovation strategically by combining productive and distortionary efforts. Using a stylized model, the paper analyses the incumbent's strategic choice and its effect on social welfare. It is shown that even from a social point of view distortionary efforts are sometimes indispensable to compensate for the potential free-riding of entrants. Moreover, regulatory policies and the influence of other network users, not competing with the incumbent, are studied.

JEL–classification numbers: L14, L97, O31.

Keywords: Innovation incentives, entry deterrence, networks, technology choice.

*Address of both authors: TU Berlin, Workgroup for Infrastructure Policy (WIP), Sekr. H 33, Straße des 17. Juni 135, 10623 Berlin, Germany. E-mail addresses: ab@wip.tu-berlin.de, km@wip.tu-berlin.de

1 Introduction

Open access regulation has become a widespread regulatory approach to network industries: Gas, electricity, telecommunications and railways are prominent examples. Network access prices are regulated at fairly low (i.e. non–monopolistic) levels in order to invite entry by network users. Competition among them is expected to benefit final consumers of network services.

However, in the longer run, open access regulation will also affect the incentives of network manager and network users to invest in innovations and investments. Due to price regulation, particularly if cost oriented, network manager's incentives to make cost reductions and quality improvements are often mitigated. Moreover, he does not internalize the reductions in operating costs of the network users. Network users will of course make efforts to reduce their own cost, but many innovations require corresponding changes in the network technology itself. In the railway industry the Train Control Systems (TCS) represent an example of such a systemic innovation (Teece, 1986). Modern TCS comprise complex computer systems on trains and trackside and carefully specified interfaces between these elements.[1]

This paper is about the incentives of network users to make such innovations. Problems might arise from two sources. On the one hand, there is a free–rider problem if one user develops and invests in a new technology and other users can participate from the innovation for free or at low cost. Traditionally, TCS for example have been developed by the national rail carriers, while entrants, mainly in transnational transport segment, 'just' had to invest in on–board units. The latest development, the European Train Control System, has been heavily subsidized by the European Commission. The free–rider problem is aggravated by the fact that the other users may directly compete with the innovator, taking away some of his monetary benefits from the innovation.

On the other hand, however, an innovation in the network technology may also raise rival's costs. Competitors will have to invest to adapt to the new network environment, but may not be able to ripe all the gains from the innovation. This will be particularly important when it affects entry decisions by new competitors. In fact, the innovator may deliberately direct the new developments so as to raise potential rivals' costs. Advanced Train Control Systems for example directly benefit only some users, in that they allow higher speeds Other decisions that crucially influence users' costs include the time path for adopting the new system and the degree of downward compatibility.

This paper directly addresses the tradeoff between incentives for productive innovations and incentives for distortions. We consider a monopolistic incumbent who makes R&D and investment decisions which will affect the network–user interface. The incumbent may be integrated with the network manager or, if not, is assumed to compensate the network manager for all costs or incurred losses. After investments have been made,

[1] For a thorough economic evaluation see NERA (2003).

an entrant may enter (at a regulated and fixed access charge) and compete with the incumbent. In this setting the incentives for R&D will depend on the particular situation. In some situations the incumbent will try to make distortionary developments aimed at raising rivals costs. In other situations he will not invest at all, since the entrant's gains from productive innovations would be too high, while distortions are impossible. However, it is also possible that distortions and productive innovations are complementary from the incumbent's point of view. Two sources of complementarities can be distinguished. First there are genuine technological complementarities; in fact, almost every new development will be accompanied by structural changes, of which some will be 'distortionary' (i.e. cost–increasing) for some other firm. Another source of complementarity is present when distortions make it more difficult for an entrant to profit from the productivity increase of the new technology. Whatever the source of complementarity is, it will encourage R&D efforts of the incumbent because he can realize productivity gains without inviting competition too much. Due to the underinvestment problems in open access networks (the free–rider problem among others) some distortionary potential that protects an innovator may be desirable from a social point of view.

In the literature, Shleifer and Vishny (1989) were the first to point out (in an organization theoretic context) that a decision maker may make structural distortions in order to entrench himself and acquire quasi–rents. However, Mitusch (2000) shows that entrenchment of this sort may be the only effective way to assure that innovations are rewarded. The same tradeoff holds for the investment of a vertically integrated network or a lead user in systemic innovations. While entrenchment activities, i.e. structural distortions in technology development, are generally undesirably, they do have the virtue of counteracting the free–rider problem and stabilizing innovation incentives.

The discrimination of entrants plays a prominent role in the literature on foreclosure and sabotage. The foreclosure literature[2] analyses the behavior of a bottleneck owner in an unregulated environment when the bottleneck (upstream) represents an essential input for (potentially) several downstream firms. The foreclosure doctrine "states that ... the bottleneck owner ... has an incentive to restrict or deny access ... to some or most of its potential buyers, and thereby to favor a downstream independent firm or a downstream affiliate" (Rey and Tirole, 1997, 7). This incentive is the result of the limited ability of the bottleneck owner to fully extract the profit of the industry unless by exclusionary behavior (otherwise, as the famous Chicago School doctrine argues, the foreclosure incentive would vanish). The problem of credibly committing to a given number of entrants, the possibility to bypass the bottleneck, or a regulated access price, among others, restrict the monopolies ability to extract profits and create incentives for foreclosure. As the existence of this incentive is a fairly general result, the here used assumption of a simple regulated access charge seems not too restrictive. Additionally,

[2]Rey and Tirole (1997) provide an authoritative survey.

the analyses show that straightforward policy rules, e.g. non-discrimination rules, can easily result in detrimental effects.

The sabotage literature[3] focuses on non-price-discrimination, i.e. the intentional degradation of the quality of access services provided to competitors (Weisman, 2001, 122). Sabotage can be targeted at raising rivals' costs or at lowering rivals' demand (Mandy/Sappington). Whether sabotage will be a profit-maximizing strategy or not hinges on (i) the increase of the downstream affiliates' profits, (ii) the direct cost of sabotage and (iii) the reduction in upstream profits (generally, total output and thus - as long as the upstream input price exceeds its marginal cost of production - upstream profits are reduced). While sabotage generally increases downstream profits, it's an empirical question whether this effect dominates the direct and opportunity costs borne by the upstream affiliate. The theoretical models indicate that the form of downstream competition (Cournot, Bertrand, existence of capacity restrictions, degree of product differentiation), the efficiency differences between the competitors, and the access price level have a crucial impact on the incentive to conduct non-price discrimination and on the decision between raising rivals' costs and lowering demand.

In a recent paper Bühler, Schmutzler, and Benz (2004) analyse quality decisions in a network industry. Their central question is, whether vertical separation reduces the incentives of the upstream firm to invest in the quality of network services. Consequently, their focus is on vertical coordination problems in a regulated environment (vertical externalities, consequences of different access price formulae). The prospects of entry, the focus of the sabotage literature and our paper, play no role in their model.

While there is now an exhaustive literature on foreclosure and sabotage, the link between innovation and these strategies has received little attention from formal economic theory. As a matter of fact, Stefanadis (1997) is to our knowledge the only one to address this link directly. He considers foreclosure as a strategy of upstream firms to succeed in R&D competition: An exclusionary contract or vertical integration with downstream firms reduces the potential market of competing upstream firms, raises - as long as economies of scale are present - their costs und thus reduces their incentive to innovate. While this setting is relevant for industries as aircraft (e.g. Airbus vs. Boeing) or system software (e.g. Microsoft vs. Netscape), this paper is concerned with the "classical" situation of a monopolistic upstream firm. Moreover, Stefanadis doesn't consider spill–over effects and the choice of technology, which are the main interest of our analysis.[4]

[3]The seminal work on sabotage is Weisman and Zhang (1997), Sibley and Weisman (1998), Mandy and Sappington (2001), Kondaurova and Weisman (2003). Mandy (2000) provides an overview.

[4]Adams and Encaoua (1994) examine strategic distortions of a monopolist's technology choice. In their model the incumbent has a first-mover advantage, i.e. given a certain technological knowledge he is the first to choose what technology to develop. The incumbent takes the subsequent technological choices of potential competitors into account and may choose a technology that is socially inefficient but discourages entry. Since the authors assume a given range of alternative technologies they do not consider incentive problems. Moreover, their model doesn't incorporate the upstream–downstream

The negligence of the link between innovations and entry deterrence may stem in part from the widespread use of standards development organizations (SDO) in network industries, especially in telecommunications.[5] In this case innovations have to pass an acceptance test in which competition preventing or hindering innovations can be sorted out, at least as long as potential competitors have voting rights or are represented by neutral regulators. But this acceptance test may be flawed: The formerly used unanimity principle gets more and more replaced by majority voting schemes or established SDO get bypassed (David and Shurmer, 1996). In the case of European railways, the national carrier is still responsible for standardization decisions in some countries, while in other countries, as Germany, there are close connections between the regulator and the national carrier and a lack of transparency in the decision process. Moreover, the lack of actual competitors makes it difficult for the regulator to assess the influence of different standards on entry decisions.

The next section sets out the model. Section 3 analyzes the innovation decision of the incumbent and evaluates it by comparison to the socially optimal decisions. Section 4 discusses the policy options of regulating technology choice. So far the analysis will be confined to the interplay of just two firms, the incumbent and the entrant. Section 5 discusses the impact of the presence of other firms operating on the network on the results derived so far. Section 6 summarizes.

2 Model

Consider an open access network with two players: an operating firm 1 (incumbent) already active on the network (or a part of) and an operating firm 2 (entrant) which might enter the network (or the same part of) and compete with firm 1. In addition, there is the network manager who may be integrated with firm 1. We assume that everyone is risk–neutral.

This model is about the incumbent's incentives to innovate. While his R&D efforts are primarily aimed at a reduction of his operating cost, the innovation will require some general changes in the user–network interface, i.e. a joint investment by himself and the network manager. After the innovation and the corresponding investments have been made (stage 1), the entrant may enter (stage 2), in which case the investments will also affect him.

We assume that the network is regulated by an open access policy. Innovative changes of the user–network interface will affect the network manager, the potential entrant, and the regulator. We assume (at first) that the regulator does not interfere with technology decisions and that the user price of the network is fixed. Thus, a network manager cannot profit directly from an innovation. However, the focus in

structure that characterizes network industries.

[5] David and Steinmüller (1994) provides an analysis of the competitive effects of SDO.

this paper is on the incumbent's innovation incentives and not on vertical coordination problems and the resulting question of vertical separation or integration. So, we simply assume that the incumbent can and will compensate the network manager for any costs incurred.[6]

Cost structure

The R&D effort by the incumbent consists of two components, $e \geq 0$ and $s \geq 0$. For simplicity we assume a quadratic effort cost function, $0.5(e^2 + s^2 - 2\gamma es)$ with $0 \leq \gamma \leq 1$. For $\gamma > 0$ the two components are complementary (the upper bound for γ assures convexity).

After an innovation has been developed, a joint investment has to be made by incumbent and network manager. An optimal investment decision minimizes the sum of the investment costs and the costs of operating the new technology. Let c_1 denote the minimized sum of investment and operating costs. We assume that the e–component of R&D effort makes investment more profitable in a deterministic way. As a consequence, c_1 is a decreasing function of e, i.e. $c_1(e)$ with $c_1' \leq 0$ (also assume $c_1'' \geq 0$).

The entrant faces a cost of entry, $F > 0$. If he enters, he will also have to make an investment decision to minimize the sum of his investment and operating costs. The resulting costs are denoted by c_2 and may depend on e and s, i.e. we have $c_2(e, s)$, and the partial derivatives are assumed to be $c_{2e} \leq 0$ and $c_{2s} \geq 0$.

Based on these assumptions (and led by the case of $\gamma = 0$) we can interpret e as a *productive effort*, since it reduces total costs, and s as a *distortionary effort*, since it increases entrant's costs. For $\gamma > 0$, the relationships are less clear but will still hold in tendency. Some illustrative examples will follow below.

For simplicity, we assume that the firms' quantitative demands for network use are fixed (for example, 1 train on the railway network, 1 unit of gas in the pipeline, etc.). The implicit cost minimization problems of the firms are therefore quite simple, since the operating costs do not depend on quantitative demand, but only on technology. In addition to the investment and operating costs, firms will also have to pay network access charges. Since quantitative demands are fixed, network access charges are also fixed, and assumed to be identical for both firms. The network access bill for each firm is denoted by a.

[6] Moreover, we assume that no distortions arise from the interaction between incumbent and network manager. This is easier to justify if the two firms are integrated. In the case of a vertically separated industry it requires that (i) the incumbent is able to make a take–it–or–leave–it offer to the network manager and (ii) the regulator allows side–payments to the network manager.

Market structure

If the entrant does not enter, let π^m denote the incumbent's 'gross profit' (by which we mean the profit *before* deducing c_1, a, and R&D costs, but after deduction of all other costs that might be incurred) and CS^m the consumer surplus. If the entrant enters, let π^d denote the identical gross profit of each firm (before deduction of F, c_1 resp. c_2, a, and R&D costs) and CS^d the consumer surplus in a duopoly.[7] In this model the gross profits and consumer surpluses are treated as fixed and given. In line with several oligopoly models we assume that $0 < \pi^d < \pi^m$ and $0 < CS^m < CS^d$ and $\pi^m + CS^m < 2\pi^d + CS^d$. Assume that network access costs satisfy $a < \min\{\pi^d, \pi^m - \pi^d\}$.

At stage 2, the entrant will enter if profit is positive, i.e. if

$$\pi^d \quad > \quad F + c_2(e, s) + a \tag{1}$$

At stage 1, the incumbent does not know the entrant's cost of entry. For him, F is distributed with c.d.f. $G(F)$ and density $g(F)$. He therefore faces a probability of entry of

$$p(e, s) \quad := \quad Prob\Big(F < \pi^d - c_2(e, s) - a\Big) \;=\; G(\pi^d - c_2(e, s) - a) \tag{2}$$

Its partial derivatives satisfy

$$\begin{aligned} p_e(e, s) &= -g(\pi^d - c_2(e, s) - a)c_{2e}(e, s) \;\geq\; 0 & (3)\\ p_s(e, s) &= -g(\pi^d - c_2(e, s) - a)c_{2s}(e, s) \;\leq\; 0 & (4) \end{aligned}$$

Since the innovation affects the probability of entry, the network's expected proceeds from the entrant will fall (or rise) from $p(0, 0)a$ to $p(e, s)a$. An integrated incumbent–network manager would take this into account, and a non–integrated incumbent would have to compensate the network manager for foregone network charges. Hence, the incumbent will not only have to refund the investment costs but also the amount $(p(0, 0) - p(e, s))a$ to the network manager.

3 Innovation decision

At stage 1, the incumbent faces the following problem:

$$\begin{aligned} \max_{e,\, s} \quad & (1 - p(e, s))\pi^m + p(e, s)\pi^d - c_1(e) - a \\ & - (p(0, 0) - p(e, s))a - 0.5(e^2 + s^2 - 2\gamma es) \end{aligned} \tag{5}$$

[7] Gross profits are identical in almost all oligopoly models if the firms' variable cost functions are identical.

A solution exists, since all terms are bounded from above in s and e. Throughout we will assume that there is a unique solution (e^*, s^*) with $0 < p(e^*, s^*) < 1$ (by appropriate choice of G). For an interior solution $(e^*, s^* > 0)$ the first–order conditions are

$$-p_e(e^*, s^*)(\pi^m - \pi^d - a) - c_1'(e^*) \;=\; e^* - \gamma s^* \tag{6}$$
$$-p_s(e^*, s^*)(\pi^m - \pi^d - a) \;=\; s^* - \gamma e^* \tag{7}$$

For welfare comparisons, various benchmarks could be employed. Instead of considering the first–best allocation (based on a perfect market environment), we take as our benchmark the effort choice which would maximize expected welfare subject to the given market structure. Expected welfare equals expected consumer surplus plus gross profits, minus expected costs, plus network's expected proceeds from access charges.[8] The expected costs of firm 2 are:

$$\begin{aligned} & p(e,s)\Big(E[F|F < \pi^d - c_2(e,s) - a] + c_2(e,s) + a\Big) \\ = \; & p(e,s)(c_2(e,s) + a) + \int_0^{\pi^d - c_2(e,s) - a} F g(F)\, dF \end{aligned} \tag{8}$$

Hence, after netting out the access charges, the welfare maximization problem is

$$\begin{aligned} \max_{e,\, s} \quad & (1 - p(e,s))(\pi^m + CS^m) + p(e,s)(2\pi^d + CS^d) \\ & - c_1(e) - p(e,s)c_2(e,s) - \int_0^{\pi^d - c_2(e,s) - a} F g(F)\, dF \\ & - 0.5(e^2 + s^2 - 2\gamma es) \end{aligned} \tag{9}$$

A solution exists, since all terms are bounded from above in s and e. Again, we assume that there is a unique solution $(\hat{e}, \hat{s})$ with $0 < p(\hat{e}, \hat{s}) < 1$. For an interior solution the first–order conditions are[9]

$$p_e(\hat{e}, \hat{s})\Big(\pi^d + CS^d - \pi^m - CS^m + a\Big) - c_1'(\hat{e}) - p(\hat{e}, \hat{s})c_{2e}(\hat{e}, \hat{s}) \;=\; \hat{e} - \gamma \hat{s} \tag{10}$$
$$p_s(\hat{e}, \hat{s})\Big(\pi^d + CS^d - \pi^m - CS^m + a\Big) - p(\hat{e}, \hat{s})c_{2s}(\hat{e}, \hat{s}) \;=\; \hat{s} - \gamma \hat{e} \tag{11}$$

The expression $\pi^d + CS^d - \pi^m - CS^m + a$ is the marginal social benefit of an increase in the probability of entry. The relevance of this expression becomes clear from comparing the private and the welfare criteria for the entry of firm 2. From a welfare point of view firm 2 should enter if the increase in consumer surplus and gross profits exceeds real costs, i.e. if

$$2\pi^d + CS^d - \pi^m - CS^m \;>\; F + c_2(e,s)$$

[8]We assume that network's marginal cost are zero.

[9]Note that the derivative of expression (8) with respect to e reduces to $p_e(e,s)\pi^d + p(e,s)c_{2e}(e,s)$.

Comparing this with the private entry criterion, (1), shows that there is *excess entry* if $\pi^d + CS^d - \pi^m - CS^m + a < 0$. In that case it would be desirable, from a welfare point of view, to raise entry barriers a bit. In the reverse case, called *deficient entry*, entry barriers should be lowered. Based on a presumption that more competition is usually desirable, we will in the following consider the case of deficient entry as the standard case.

Comparing the private and the social first–order conditions, (6) and (7) with (10) and (11), one would be surprised if private behavior, (e^*, s^*), coincided with socially optimal behavior, $(\hat{e}, \hat{s})$. In general, one can identify the following sources of inefficiency.

Effects of the marginal probability of entry on innovation. Since the incumbent dislikes entry (i.e. $\pi^m - \pi^d - a > 0$), the derivatives of the probability of entry, p, enter with a negative sign in his first–order conditions, (6) and (7). This suggests that the marginal probability of entry acts as a disincentive for productive efforts (as $p_e \geq 0$) and a stimulus for distortionary efforts (as $p_s \leq 0$). In fact, one can show that e^* is decreasing and s^* increasing in the relative value of monopoly, $\pi^m - \pi^d - a$, if the cross–effects in the first–order conditions are sufficiently small.[10] With respect to the productive efforts, note the similarity of the probability of entry to a holdup. Here, as well as in a holdup problem, the investor faces the problem that someone else might claim a share of his own returns of his investment.

In contrast to the incumbent, society as a whole appreciates entry (in the case of deficient entry). Note that entry does not only redistribute the social returns on an investment, it also leads to an increase of these returns. Therefore the derivatives of p enter with a positive sign in the welfare first–order conditions, (10) and (11), suggesting that productive efforts are appreciated and distortionary efforts not. It can be shown that $\hat{e}$ is increasing and $\hat{s}$ decreasing in the marginal social benefit of an increase in the probability of entry, $\pi^d + CS^d - \pi^m - CS^m + a$, if the cross–effects in the first–order conditions are sufficiently small (same conditions as in footnote 10).

Effects of the free–rider problem on innovation. Society as a whole is also interested in the expected costs of firm 2. This is captured by the appearance in (10) of the expected marginal cost reduction of firm 2 due to productive efforts, pc_{2e}. Likewise, firm 2's expected marginal cost increase due to distortionary efforts, pc_{2s}, appears in (11). These effects have the tendency of making productive efforts even more and distortionary efforts even less desirable. In contrast, the corresponding terms are missing in the incumbent's first–order conditions, (6) and (7), since he does not internalize the effects on firm 2's costs. A better way of saying this: the entrant does not share in the R&D costs even if he benefits. This is the free–rider problem.

For a closer look at these effects we now discuss some simple illustrative examples.[11]

[10] I.e. if the effects of s on (6) and of e on (7) are small. This is the case if γ and p_{es} are small enough (for example, $g' \to 0$ and $c_{2es} \to 0$ imply $p_{es} \to 0$). Then $de^*/d\pi^m < 0$ and $ds^*/d\pi^m > 0$.

[11] We will continue with the assumption (if necessary) that the solutions are unique. Boundary

Example 1: $c_1(e) = c_1(0)$ and $c_2(e,s) = c_1(0) + \beta s$ with $\beta > 0$. The innovation is completly unproductive (net of investment costs). It only serves to raise rival's costs.

In this example, $c_1' = c_{2e} = 0$ and $c_{2s} = 1$. Hence $p_e = 0$ and $p_s = -g(\pi^d - c_1(e) - s - a) < 0$. The incumbent's solution is given by $e^* = \gamma s^*$ and $s^* = g(\pi^d - c_1(e^*) - s^* - a)(\pi^m - \pi^d - a)\beta/(1-\gamma^2)$ which implies $s^* > 0$. He makes a distortionary effort in order to raise entry barriers for firm 2.

The welfare solution also implies $\hat{e} = \gamma \hat{s}$, however, unless the *excess* entry condition is satisfied (to a sufficiently large extent), it would be socially optimal to have $\hat{s} = 0$. Thus, in the case of *deficient* entry, the incumbent overinvests, i.e. $s^* > \hat{s} = 0$ and (for $\gamma > 0$) $e^* > \hat{e} = 0$. His decisions imply two sources of inefficiency. First, there is a waste of resources, since the incumbent spends on R&D where he shouldn't, and second, barriers to entry are increased where they should be lowered, with the consequence that the social loss due to monopoly is more likely to persist.[12]

Example 2: $c_1'(e) < 0$ and $c_2(e,s) = c_1(e)$ and $\gamma = 0$. Productive efforts will benefit the incumbent and the entrant alike. Distortionary efforts are not an issue.

In this example, $c_1' = c_{2e} < 0$ and $c_{2s} = 0$. Hence $p_e = -g(\pi^d - c_1(e) - a)c_1'(e) > 0$ and $p_s = 0$. Clearly, $s^* = 0$ and $\hat{s} = 0$. For the incumbent's solution, (6) reduces to

$$e^* \;=\; -c_1'(e^*)\Big(1 - g(\pi^d - c_1(e^*) - a)(\pi^m - \pi^d - a)\Big) \tag{12}$$

For the welfare solution, (10) implies

$$\hat{e} \;=\; -c_1'(\hat{e})\Big(1 + p(\hat{e}) + g(\pi^d - c_1(\hat{e}) - a)(\pi^d + CS^d - \pi^m - CS^m + a)\Big) \tag{13}$$

This implies for the case of deficient entry that the incumbent underinvests, i.e. $e^* < \hat{e}$. The gap is due to two reasons. First, the incumbent does not internalize the cost reduction of the potential entrant (or, better, the entrant does not share in the R&D costs). This effect is captured by the probability of entry, p, which appears in (13) but is missing in (12). Second, incumbent's innovation incentives are further reduced by the fact that a shared productivity increase raises firm 2's probability of entry (the density g in (12)). From a welfare point of view, in contrast, the stimulation of entry is a positive effect (in the case of deficient entry), as can be seen in (13).

Example 3: $c_1(e) = 1 - e$ and $c_2(e,s) = 1 - (1-\beta s)e$ with $\beta > 0$ (for $e \leq 1$ and $\beta s \leq 1$). Moreover, assume $g(F) \equiv 1$ (uniform distribution), $\pi^d = 1 + a$, and $\delta := \pi^m - \pi^d - a \in (0,1)$.

In this example, $c_1' = -1$, $c_{2e} = -(1-\beta s)$, and $c_{2s} = \beta e > 0$. Hence, $c_{2es} = \beta > 0$, i.e. distortionary efforts reduce firm 2's marginal benefit from the productive efforts.

solutions are characterized as usually.

[12] The example can be generalized to $c_1'(e) \leq 0$ and $c_2(e,s) = (1-\alpha)c_1(0) + \alpha c_1(e) + \beta s$ with $\alpha \geq 0$ and $\beta > 0$. The e–efforts are then really productive but, for α small enough and $\gamma > 0$, there will still be overinvestment, i.e. $s^* > \hat{s} \geq 0$ and $e^* > \hat{e} > 0$.

The uniform distribution implies $p_e = -c_{2e} > 0$ and $p_s = -c_{2s} < 0$ and $p(e,s) = \pi^d - c_2(e,s) - a = (1-\beta s)e$. Incumbent's first–order conditions reduce to

$$-(1-\beta s^*)\delta + 1 = e^* - \gamma s^* \quad \text{and} \quad \beta e^* \delta = s^* - \gamma e^*$$

Note that e and s are complementary from the incumbent's point of view, first because $\gamma \geq 0$, and second because distortionary efforts reduce the marginal effect of the productive efforts on the probability of entry (i.e. $p_{es} = -\beta$). The equations solve for

$$e^* = \frac{1-\delta}{1-(\beta\delta+\gamma)^2} \quad \text{and} \quad s^* = (\beta\delta+\gamma)\frac{1-\delta}{1-(\beta\delta+\gamma)^2}$$

Hence e^* and s^* are increasing in the complementarity parameters γ and β. The interior solution is valid unless γ and β are very high.[13]

Welfare (assuming the case of deficient entry) would be maximized at the boundaries $\hat{s} = 0$ and $\hat{e} = 1$. Thus, the incumbent overinvests in distortionary efforts and underinvests in productive efforts.

4 Regulating technology choice

The welfare comparions made in the last section are interesting for interpretations, but not for practical purpose. It will usually not be possible to impose the socially optimal choices $(\hat{e}, \hat{s})$ on the incumbent or an integrated firm directly. In this section we will investigate a policy instrument which might be available in practice.

Regulatory institutions might be able to identify certain technological strategies which are obviously distortionary, and prohibit the network manager to implement them. An example can be the use of an unusual programming language (or an expensive program) in software design, if the same programming purpose can also be achieved with a commonly available language (or a cheaper program). Banning such strategies from being followed will make it more difficult to make distortions. This can be modelled either as an increase in the costs of distortionary efforts or, at given effort costs, as a decrease in the effects of s on c_2. In the above examples we have introduced the parameter β as a weight of the marginal effect of s on c_2. An intelligent regulation of technology choice can be interpreted as a lowering of β.

In Example 1, it would clearly be optimal to set $\beta \to 0$ since this will avoid any distortions. In Example 2, in contrast, nothing can be done to alleviate the underinvestment problem. Example 3 is more interesting. On first sight one might want to set $\beta \to 0$, since this will induce $s^* = \hat{s} = 0$. However, there is an underinvestment

[13] Besides $e \leq 1$ and $\beta s \leq 1$, concavity also requires $\beta\delta + \gamma < 1$. For a numerical example see footnote 14 below.

[14] The figure is based on the following numerical specifications: $\gamma = 0.5$, $\pi^m = 2.4$, $\pi^d = 1.3$, $CS^d = 1.3$, $CS^m = 0.2$, $a = 0.3$. The interior solution given in Example 3 is valid for all $\beta < 0.557$.

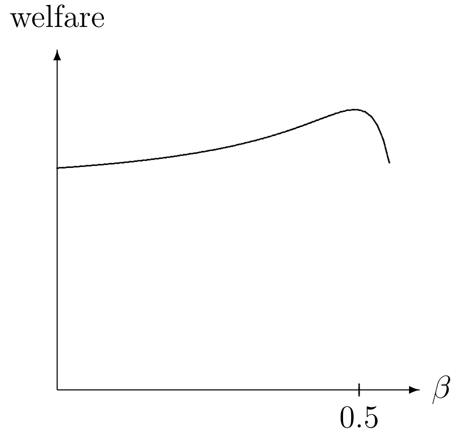

Figure 1: Welfare in Example 3 as a function of β

Shown for $\beta \leq 0.55$.[14]

problem with respect to the *productive* efforts, and these are complementary with distortionary efforts from the incumbent's point of view. It might therefore be preferable to allow some distortions. Figure 1 shows social welfare, resulting from the incumbent's choices e^* and s^*, as a function of β for a numerical example. Welfare is increasing in β initially, and attains a maximum at about $\beta = 0.5$. It would therefore not be advisable to push β below this level by a ban on distortionary technological strategies.

The example illustrates an important general point. Distortionary efforts are just one aspect of the problem. In addition, there is the free–rider problem which is aggravated by the fact that the entrant will even 'steal' some of the investor's private returns on investment if he enters. The latter problem will ceteris paribus lead to a deficiency of productive efforts. The ability to make distortions counteracts this effect, if distortionary and productive efforts are complementary from the investor's point of view, i.e. if either $\gamma > 0$ or $p_{es} < 0$ or both. The incumbent entrenches himself by making distortions, i.e. secures a larger share of the investment returns for himself, and this makes it more worthwhile for him to make productive efforts. Allowing distortions can therefore be useful for inducing higher productive efforts.

5 The impact of other network users

So far our discussion focused on the interaction of just two (potential) network users. In reality, there will be many more users. If a network has characteristics of a natural monopoly there should be as many users as possible to contribute to its financing. The purpose of this section is to investigate the robustness of our previous discussion to the presence of other network users. We will assume that there is one other firm, called firm 3, which is already in the market, but not competing with the incumbent (or entrant) for customers. Firm 3 supplies a different market niche. For example, if firms 1 and 2 are passenger train operating companies, firm 3 is a freight company, or if firms 1 and 2 are gas suppliers for one region, firm 3 uses this part of the network only to pass on gas to another region supplied by it. This allows us to abstract from the effects of additional competition and focus on the effects of compatibility.

The pivotal assumption is that innovation affects the costs of firm 3 in much the same way as those of firm 2. That is, we have $c_3(e,s)$ with $c_{3e} \leq 0$ and $c_{3s} \geq 0$. Thus, firms 1 and 3 are non–integrated. If the incumbent makes distortionary efforts, in order to raise entrant's costs, it will simultaneously hurt firm 3 as well. Since firm 3 contributes to network financing, this will be a disadvantage. In order to model this we make the following assumptions. The gross profit of firm 3 is denoted by $\tilde{\pi}$ and the associated consumer surplus by $\widetilde{CS}$; both are taken as fixed and given. At stage 1 (innovation), the future gross profit of firm 3 is a random variable, distributed with c.d.f. $\tilde{G}(\tilde{\pi})$ and density $\tilde{g}(\tilde{\pi})$. Firm 3 will leave the market if gross profit does not cover costs. Assuming that its network charges are a (same as that of firms 1 and 2), firm 3 will only stay in the market if $\tilde{\pi} \geq c_3(e,s) + a$. Hence its probability of staying in the market is

$$q(e,s) \quad := \quad Prob\Big(\tilde{\pi} > c_3(e,s) + a\Big) \;=\; 1 - \tilde{G}(c_3(e,s) + a) \tag{14}$$

Its partial derivatives satisfy

$$q_e(e,s) \;=\; -\tilde{g}(c_3(e,s) + a)c_{3e}(e,s) \;\geq\; 0 \tag{15}$$

$$q_s(e,s) \;=\; -\tilde{g}(c_3(e,s) + a)c_{3s}(e,s) \;\leq\; 0 \tag{16}$$

In order to gain network manager's consent for an innovation, a non–integrated incumbent will have to refund any expected losses in network access charges paid by firm 3. Since the latter's probability of staying in the market will fall (or rise) from $q(0,0)$ to $q(e,s)$, the incumbent has to refund the amount $(q(0,0) - q(e,s))a$ to the network manager (if negative, his payments to the network manager are reduced). If firm 1 is integrated with the network manager, the same amount enters the expected profit of the integrated firm. It has to be subtracted from the payoff given in (5). As a consequence, the first–order conditions are altered as follows:

Add $q_e(e^*,s^*)a \geq 0$ to LHS of (6) and $q_s(e^*,s^*)a \leq 0$ to LHS of (7).

Therefore, the presence of firm 3 on optimal R&D decisions will 'usually' have the impact of increasing e^* and reducing s^*.[15] Since firm 3 is not a competitor, the incumbent would prefer to have this firm in the market so that he can avoid compensation payments. This tends to raise the incentives for productive efforts and reduces those for

[15]This and the following general statements on comparative statics are based on the assumption that cross–effects between the first–order conditions for e and s are not too large. See footnote 10.

distortionary efforts, due to their respective effects on the probability of firm 3 staying in the market.

Now consider the welfare perspective. The expected contribution of firm 3 to welfare (after netting out its access charges with the proceeds of the network manager) is

$$\int_{c_3(e,s)+a}^{\infty} (\tilde{\pi} + \widetilde{CS} - c_3(e,s))\tilde{g}(\tilde{\pi})\, d\tilde{\pi}$$

This has to be added to expression (9). As a consequence, the welfare first–order conditions are changed as follows:

$$\begin{aligned} &\text{Add} \quad q_e(\hat{e},\hat{s})(\widetilde{CS}+a) - q(\hat{e},\hat{s})c_{3e}(\hat{e},\hat{s}) > 0 \quad \text{to LHS of (10)} \\ &\text{and} \quad q_s(\hat{e},\hat{s})(\widetilde{CS}+a) - q(\hat{e},\hat{s})c_{3s}(\hat{e},\hat{s}) < 0 \quad \text{to LHS of (11).} \end{aligned}$$

This usually has the effect of increasing the socially optimal level of $\hat{e}$ and decreasing that of $\hat{s}$. Thus, qualitatively, the incumbent's interests in firm 3 is aligned with welfare interests. However, the effects of e and s via firm 3 on welfare are by far larger than the respective effects on incumbent's profit. Welfare also takes into account the consumer surplus and the costs of firm 3. That the latter costs are missing in the incumbent's considerations is a recurrence of the free–rider problem (which adds to the free–rider problem with respect to firm 2). The free–rider problem is clearly aggravated if more firms would benefit from the incumbent's R&D efforts, and not pay for it.

In order to overcome the free–rider problem firms 1 and 3, which are already in the market at stage 1, might set up an R&D joint venture. Let's consider a perfect joint venture (i.e. without any internal free–rider or team production problems) which seeks to maximize the expected joint surplus of firms 1 and 3. It would maximize:

$$\text{Expression (5)} - (q(0,0) - q(e,s))a + \int_{c_3(e,s)+a}^{\infty} (\tilde{\pi} - c_3(e,s) - a)\tilde{g}(\tilde{\pi})\, d\tilde{\pi}$$

Let the solution of the R&D joint venture's maximization problem be denoted by (e^{jv}, s^{jv}). The first–order conditions are

$$-p_e(e^{jv},s^{jv})(\pi^m - \pi^d - a) - c_1'(e^{jv}) + \underbrace{q_e(e^{jv},s^{jv})a - q(e^{jv},s^{jv})c_{3e}(e^{jv},s^{jv})}_{>0} = e^{jv} - \gamma s^{jv}$$

$$-p_s(e^{jv},s^{jv})(\pi^m - \pi^d - a) + \underbrace{q_s(e^{jv},s^{jv})a - q(e^{jv},s^{jv})c_{3s}(e^{jv},s^{jv})}_{<0} = s^{jv} - \gamma e^{jv}$$

Since the free–rider problem with respect to firm 3 is overcome in the joint venture, one would usually expect that $\hat{e} > e^{jv} > e^*$ and $s^* > s^{jv} > \hat{s}$. Note, moreover, that, due to the presence of firm 3, e^* can be expected to be higher, and s^* lower, than they would be without that firm.

One may therefore draw the following general conclusions. The issue of purely distortionary efforts (s) is less of a problem if network use is distributed over many firms serving different niches of the market. That issue will be especially relevant if there is one single dominant firm which serves all market niches simultaneously and fears entry of competitors in various niches (as, for example, in the case of railways in many countries). The free–rider problem, on the other hand, is aggravated when there are a multitude of network users. Hopefully, these users are smart enough to set up efficient R&D joint ventures.

6 Summary

Positive spill–overs of innovations are a common phenomenon. In network industries they will regularly occur, if an innovation affects the network–user interface. However, innovations affecting the network–user interface can also have negative spill–overs on competitors. The mix of positive and negative spill–overs will in turn affect the innovator's incentives to invest. Moreover, an innovator can often influence the relative strength of positive and negative spill–overs by his choice of technology. His competitive and technological environment will therefore affect his decisions on the technological content of an innovation.

This paper aimed at showing and analyzing the tradeoffs involved. If there is ample scope for distortions, with only a little productive effect, unproductive innovations are likely to occur with the effect of making the network less accessible to potential entrants. On the other hand, if no distortions are possible at all, the prospects for productive innovations are not very good either. The free–rider problem, aggravated by the fact that an entrant will even take away some of the incumbent's own future returns, will lead to a deficiency of innovation. However, it is likely that distortionary and productive innovations are complementary. The ability to make distortions will then restore some of the incentives to make innovations.

It is conceivable that a regulatory technology policy can reduce the potential to make distortions. While this might be helpful in some circumstances, it will not help to overcome a general underinvestment problem. On the contrary, if distortionary and productive innovations are complementary, then prohibiting distortions is likely to inhibit productive innovations. This policy instrument should therefore be handled with care.

This conclusion seems to be reinforced once the picture is broadened and the presence of other firms on the network is taken into account. If the proceeds of the network depend on the presence of many independent users the incentives to make distortions are reduced, while the incentives for productive efforts are increased. However, in view of the larger number of potential beneficiaries of an innovation, the free–rider problem will be larger. It is reinforced by the fact that the complementarity between distortionary and productive innovations is reduced. Thus, when a market develops on a network, the problem of technological distortions is likely to be reduced while the free–rider problem will become more relevant. Network users should then take resort to institutional solutions of the free–rider problem, for example by setting up R&D joint ventures.

References

Adams, W. J. and Encaoua, D. (1994). Distorting the direction of technological change. *European Economic Review*, Vol. 38, 663-673.

Buehler, S., Schmutzler, A. and Benz, M.-A. (2004). Infrastructure Quality in Deregulated Industries: Is there an Underinvestment Problem? *International Journal of Industrial Organization*, Vol. 22, 253-267.

David, P. A. and Steinmueller, E. W. (1994). Economics of Compatibility Standards and Competition in Telecommunication Networks. *Information Economics and Policy*, Vol. 6, 217-241.

David, P. A. and Shurmer, M. (1996). Formal Standard–Setting for Global Telecommunications and Information Services. *Telecommunication Policy*, Vol. 20, 789-815.

Kondaurova, I. and Weisman, D. L. (2003). Incentives for Non–price Discrimination. *Information Economics and Policy*, Vol. 15, 147-171.

Mandy, D. M. and Sappington, D. E. (2001). Incentives for sabotage in vertically–related industries. University of Missouri – Columbia mimeo.

Mandy, D. M. (2000). Killing the Goose That May Have Laid the Golden Egg: Only the Data Know Whether Sabotage Pays. *Journal of Regulatory Economics*, Vol. 17, 157-172.

Mitusch, K. (2000). Job Independence as an Incentive Device. *Economica*, Vol. 67, 245-263.

NERA (2000). *Safety Regulations and Standards for European Railways.* London.

NERA (2003). *Train Protection – Review of Economic Aspects of the Work of the ERTMS Programme Team.* London.

Rey, P. and Tirole, J. (1997). A Primer on Foreclosure. Forthcoming in *Handbook of Industrial Organization*.

Shleifer, A. and Vishny, R. W. (1989). Management Entrenchment: The Case of Manager–Specific Investments. *Journal of Financial Economics*, Vol. 25, 123-139.

Sibley, D. S. and Weisman, D. L. (1998). Raising Rivals' Costs: The Entry of an Upstream Monopolist into Downstream Markets. *Information Economics and Policy*, Vol. 10, 451-470.

Stefanadis, C. (1997). Downstream Vertical Foreclosure and Upstream Innovation. *Journal of Industrial Economics*, Vol. 45, 445-456.

Teece, D. J. (1986). Profiting from Technological Innovation: Implications for integration, Collaboration, Licensing and Public Policy. *Research Policy*, Vol. 15, 285-305.

Weisman, D. L. (2001). Access Pricing and Exclusionary Behavior. *Economics Letter*, Vol. 72, 121-125.

Weisman, D. L. and Zhang, M. (1997). Opportunities vs. incentives to discriminate. *Telecommunications Policy*, Vol. 21, 309-316.