Following the Follower in the Innovation Game

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September 10, 2003

Abstract

We consider an innovation game in which the role of each player is well-defined: first an innovator invests, followed by a second firm that can be an imitator or an improver. However, if we introduce legal requirements that followers have to respect (for instance patents), the role are formally reversed; innovators behave like followers since the decision of the second firm is already (partially) fixed. We cross this observation with the fact that firms' investment decisions can be detrimental or beneficial to rivals and partners. For instance, the innovators can be hurt by the imitator's investment, and the imitator may benefit from the innovator's investment, due to spillover effects. In this setting depending on the spillover effects we investigate whether innovators over or under invest when there exist local limitations to imitation and improvement of innovations.

Keywords: Innovation, spillover, leadership, R&D regulation

JEL classification: K4 (Legal Procedure); L11 (Market structure); O31 (Innovation and Invention: Processes and Incentives).

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1 Introduction

The innovation game is a complex dynamic process where no one can truly assert that his brand new product or her cost-killer method comes out of nothing. All innovators benefit from former research efforts, either private or public, either access-free or protected by property rights.[1] In some cases, the innovation is Pareto improving because it does not hurt the benefits of any incumbent and it can even be a good opportunity to improve the spectrum of services provided by some ancient products or to decrease its production and/or use cost. But in many cases, the innovation is detrimental for some agents. It can be mildly detrimental when it marginally infringes the claims of some property-right owner. In this case, the right-owner can tolerate the presence of a competing product if it is sufficiently differentiated because fighting commercially or legally against entry would cost more than the lost revenues. The innovation can strongly hurt the benefits of some incumbent when it is a mere copy of the incumbent's product (and it should not be called an 'innovation'). It can even result in the exclusion of a former seller when the innovation is the drastic improvement of an ancient product or process. Because today's entrants are tomorrow's incumbents, innovators can rationally anticipate the threat of lost revenues due to entry and play strategically. For instance, an innovator who cannot benefit from a good protection against copying has an incentive to underinvest. Symmetrically, an innovator who expects complementary discoveries that will increase his benefits has an incentive to overinvest.[2] This explains why the conventional framework for the economic analysis of intertemporal competition between an innovator and his potential competitors is a sequential game where the innovator decides on his effort anticipating the reaction function of future entrants.

The trade-off between the advantages for society of a high innovation activity and the mostly private cost of the effort to innovate ineluctably pushes governments to intervene in the innovation process. The most common intervention consists in the definition of property rights that will allow private investors to harvest the profits generated by their effort rather than to share those profits with free riders. For candidates to entry (either mere copiers or true improvers),

[1] The 'cumulativeness' of innovations is analyzed in Scotchmer (1999). "We are like dwarfs on the shoulders of giants so that we can see more than they, and things at a greater distance not by virtue of any sharpness of sight on our part, or any physical distinction but because we are carried high and raised up by their giant size", is attributed to Bernard de Chartres, a philosopher of the 12th century.

[2] O'Donoghue, Scotchmer and Thisse (1998) study a dynamic game where improvements arise randomly. They show that, if the protection against imitation is perfect whereas the protection against improvement is not, innovators tend to overinvest or underinvest, depending on the rate at which ideas occur to innovators. If ideas are too frequent, innovators cannot fully benefit from their innovations, and thus tend to underinvest. On the other hand, if they are not that frequent, firms tend to overinvest.

it means that they will have to step over administrative or economic thresholds in order to be accepted. For example, the novelty requirement obliges challengers to invest in 'non-imitation' much more than what they intended to do. They will not be allowed to enter if they do not differentiate their product sufficiently.[3] But this type of requirement has an effect that, so far, has not been analyzed in the literature on R&D: each time the legal requirement is binding, newcomers are not really reacting to the investment decisions of the innovator. Their own 'research' expenditures are fixed by law or regulation. Actually, we can even say that the roles are reversed. When the innovator already knows what the followers will have to spend because of legal restrictions, he is the true follower. It results that the question to know whether it is a good incentive for innovators to have a strict regulation by means of patents, copyrights and all the variety of intellectual property rights can (partially) be restated as "When does the innovator invest more? When he is the leader of the innovation game or when he behaves like a follower?"

The paper analyzes this problem using an elementary model of competition between two firms when there exist spillovers between their profit functions.

Contrary to the patent race literature where firms compete to be the first to make the same discovery (Reinganum, 1989), we consider that some firms make innovations, whereas other firms follow on the innovators. Consequently, these firms do not compete for the same discoveries, and they play very different roles in the dynamic process of innovation. We thus depart from this literature as we study the investment decisions when there is no race. Our approach is closer to the 'cumulative' approach in which innovation builds upon previous discoveries (Scotchmer, 1999, O'Donoghue, Scotchmer and Thisse, 1998). However, we do not adopt the random dynamic structure of O'Donoghue et al. (1998). We simply assume that after an innovation has been made the follower observes it and decides how much to invest in imitation. The role of each player is well defined: the leader innovates and the follower imitates, develops or improves. Furthermore we implicitly assume that the patent protection is imperfect, as imitation is legal within certain limits. This has first been studied by Gallini (1992) who determines the appropriate protection against imitation as well as the optimal duration of the patent in order to prevent imitation. However, it is not necessarily the case that entry should be prevented. If there exist positive externalities that flow from the innovator (respectively the follower) to the follower (respectively the innovator), entry, even an imitation, can boost innovation rather than being detrimental. We explore the incidence of negative and positive externalities on the investment decision of innovators and followers.

[3]In Scotchmer and Green (1990), it is argued that a 'strong' novelty requirement that limits the number of patentable improvements can be socially better than a 'weak' novelty requirement because it gives greater incentives to race and the race accelerates progress.

The paper is organized as follows. The hypothesis are exposed in section 2. Section 3 gives the details of the equilibria with and without exogenous constraint in four cases. These cases correspond to the configurations where the innovator benefits or suffers from the competitor's investment combined with those where the competitor benefits or suffers from the innovator's investment. In order to keep a coherent view of the problem, we mainly restrict the illustrations of the four configurations to the Information and Communication Industry, namely the music industry, the software industry, the hardware industry and the video game industry. In section 4, we discuss several alternative explanations for research spillover and we consider the merger (or joint venture) solution. Section 5 concludes.

2 The Model

The players:

We consider a sequential model with two firms: an innovator (I) and a potential entrant (E). Both have to invest in order to develop their products but E is a follower, which means that she will be second to choose, after observing the choice of I and her choice will be constrained by some Intellectual Property Rights (IPRs). Let us denote by x_I the investment decision of I. We assume that there is no uncertainty concerning the innovation and that it is introduced and patented at the same moment. The potential entrant (or follower) observes the investment decision made by the innovator (through the innovation that has been brought about) and decides how much to invest in imitation or development. Let us denote x_E this imitation or development decision. In order to keep the model as general as possible we do not precisely specify the imitation decision. It can be a differentiation decision (how far from the existing product the follower wants her product to be), an improvement decision (how better the follower wants her product compared to the initial product), or an application decision (how many applications the follower wants to introduce in the market). As we are mainly interested in the impact of the investment decision of one firm on the decision of the other firm, we simply consider the following reduced profit functions for each firm:[4]

$$V_I(x_I, x_E) = x_I - \frac{(x_I)^2}{2} + \eta_I x_I x_E \tag{1}$$

$$V_E(x_E, x_I) = x_E - \frac{(x_E)^2}{2} + \eta_E x_I x_E \tag{2}$$

[4] These profit functions are to be viewed as the profit faced by the decision makers at the first stage of a two-stage game where the second stage equilibrium has been solved. See for instance d'Aspremont and Jacquemin (1988), where firms first engage in cost-reducing R&D and then compete in quantities on a homogeneous good market. In Motta (1992), first R&D is aimed at increasing the quality of products, then firms compete on a differentiated good market.

where η_i $(i = I, E)$ represents a spillover effect that can take positive or negative values, with $|\eta_E| < 1$, $|\eta_I| < 1$ and $\eta_E \eta_I < 1/2$. As $\eta_I = \frac{\partial^2 V_I(.)}{\partial x_E \partial x_I}$ and $\eta_E = \frac{\partial^2 V_E(.)}{\partial x_E \partial x_I}$, when η_I (respectively η_E) is positive, the innovator (respectively the follower) benefits from the effort of the other firm. On the contrary, η_I (respectively η_E) negative corresponds to a negative externality borne by the innovator (respectively the follower). In the literature about knowledge externalities, spillovers are in general positive externalities as they indicate the transmission of useful information. They can be included in the final cost reduction and be symmetric (D'Aspremont and Jacquemin, 1988), asymmetric (De Bondt and Henriques, 1995), or they can intervene in each firm's final R&D investment (Kamien, Muller and Zang, 1992). Most of the findings in these studies depend on the size of those spillovers: they can be small or large compared to a certain cut-off value (that is model-dependent). Here, we do not specify where the externalities intervene, and thus we consider that spillovers can be either positive or negative. Loosely stated what we call "negative spillovers" correspond to small spillovers in the literature, whereas "positive spillovers" would correspond to large spillovers.

The regulation:

However, the follower is constrained by patent or copyright laws or specific regulations to respect some market boundaries. In our elementary setting these constraints will be modelled as investment requirements. If for instance the follower invests to differentiate her product, the government can oblige her to invest at least a minimum level, say $\underline{x}_E$. Indeed, when he receives a patent, the innovator is being granted the right to protect a defined segment of the market (if we consider horizontal differentiation) or a certain number of applications, or improved versions of his product (if we consider vertical differentiation). Symmetrically, it can be the case that there exists some upper limit $\overline{x}_E$ that the entrant is not allowed to exceed because it would be viewed as an obvious infringement of the innovator's rights.[5] Consequently, the entrant has to respect the constraints $x_E \leq \overline{x}_E$, and / or $x_E \geq \underline{x}_E$. In centrally planned systems, we would have $\underline{x}_E = \overline{x}_E$ so that entrants would have no choice at all since all R&D decisions are controlled by one unique principal. An alternative restriction could be an exclusion zone $x_E \notin [\underline{x}_E, \overline{x}_E]$. This would mean that entry is accommodated only either if the challenger operates on small scale which does not deprive the innovator of large benefits or on the contrary if she invests large amounts of money, which could represent an improvement detrimental for the incumbent but beneficial for consumers. The exclusion zone is the one that best corresponds to the patent system. However, in order to keep the model as simple as possible, we will only consider the two following elementary restrictions: either $x_E \leq \overline{x}_E$ or $x_E \geq \underline{x}_E$ and we will analyze the consequences of a change in $\overline{x}_E$ or $\underline{x}_E$ on the investment of the innovator.

[5] When $\overline{x}_E = 0$, entry is totally forbidden.

Alternative equilibria:

The best unconstrained choice of the follower is

$$x_E(x_I) = 1 + \eta_E x_I \tag{3}$$

since she knows x_I at the time she makes her decision.

Anticipating the reaction function (3), the best choice of the innovator is

$$x_I^* = \arg\{-x_I + 1 + \eta_I[x_E(x_I) + x_I \frac{dx_E(x_I)}{dx_I}] = 0\}. \tag{4}$$

We consider three alternative cases:

1. The benchmark case in which entry is prohibited or technically impossible (either because $\overline{x}_E = 0$ or $\underline{x}_E$ is too big[6]) so that $x_E \equiv 0$. Let

$$x_I^m = 1 \tag{5}$$

denote the investment in R&D made by the unchallenged monopoly.

2. The second case corresponds to constrained choices by the followers, because either $x_E(x_I) < \underline{x}_E$ or $x_E(x_I) > \overline{x}_E$. Depending on the value of the exogenous requirement, the patentholder will choose

$$\text{either} \quad \underline{x}_I = 1 + \eta_I \underline{x}_E \quad \text{or} \quad \overline{x}_I = 1 + \eta_I \overline{x}_E. \tag{6}$$

Let $\widehat{x}_I(x_E)$ be the best choice of the innovator when he anticipates $dx_E/dx_I \equiv 0$. In particular, we have $\widehat{x}_I(\underline{x}_E) = \underline{x}_I$ and $\widehat{x}_I(\overline{x}_E) = \overline{x}_I$.

3. We now turn to the case where the follower observes the value of x_I and can choose x_E without any restriction. She therefore reacts according to $\frac{dx_E(x_I)}{dx_I} = \eta_E$. Using this information, from (4) we can write x_I^* as a best anticipation to x_E

$$x_I(x_E) = \frac{1 + \eta_I x_E}{1 - \eta_E \eta_I}. \tag{7}$$

In the absence of binding requirement, the equilibrium levels of investment in the sequential

[6] There exists a cut-off value $x_E^{\max}$ such that, for any $\underline{x}_E > x_E^{\max}$ the follower never enters as her payoff becomes negative.

game are[7]

$$x_I^* = \frac{1+\eta_I}{1-2\eta_E\eta_I}, \tag{8}$$

$$x_E^* = \frac{1+\eta_E(1-\eta_I)}{1-2\eta_E\eta_I}. \tag{9}$$

These equilibrium levels vary with the spillover parameters in a non-trivial manner.[8] The equilibrium level of investment of each firm i, x_i^* for $i = E, I$ depends on its "own" spillover parameter, i.e., η_i as well as on the spillover parameter of the other firm, i.e., η_j for $j \neq i$ and $j = E, I$. We thus investigate how each equilibrium investment varies with the two spillover effects. The investment of the entrant is always increasing with η_E, for any value of $\eta_I \in (-1, 1)$ as $\partial x_E^*/\partial \eta_E = (1+\eta_I)/(1-2\eta_E\eta_I)^2$. This increasing relationship does not hold any longer for the equilibrium investment of the innovator. Indeed, it increases with η_I only for high values of η_E, i.e., $\eta_E > -1/2$ as $\partial x_I^*/\partial \eta_I = (1+2\eta_E)/(1-2\eta_E\eta_I)^2$. For very negative values of η_E, i.e., $\eta_E < -1/2$, the innovator invests less as η_I increases. This is due to the sequential structure of our game.

We now investigate how the equilibrium levels of investment change after a change in the other spillover parameter. The investment of the entrant increases with η_I either for small values of $\eta_E < -1/2$ or for positive values of η_E, as $\partial x_E^*/\partial \eta_I = \eta_E(1+2\eta_E)/(1-2\eta_E\eta_I)^2$. For values of $\eta_E \in (-1/2, 0)$, the equilibrium level of investment of the entrant decreases with η_I. Finally, the equilibrium investment of the innovator is increasing (respectively decreasing) with η_E if $\eta_I < 0$ (respectively $\eta_I > 0$) as $\partial x_I^*/\partial \eta_E = -2\eta_I(1+\eta_I)/(1-2\eta_E\eta_I)^2$.

It is clear that the comparison of the optimal investments of the innovator given by (5), (6), and (8) depends on the sign of the spillover parameters η_E and η_I.

We now detail four configurations that we classify according to the relevance of both signs for a specific branch of the ICT industry. For instance, $\eta_E > 0$ and $\eta_I > 0$ corresponds to an industry where both externalities are positive: the more the innovator (respectively the follower) invests, the higher the profit of the follower (respectively the innovator). This corresponds to the externalities that arise in the computer industry where I stands for the microprocessor producers and E represents the software developers. They both benefit from the effort of the other.

[7] Solving (3) and (4) gives the same result as solving the system of equations (3) and (7). We use the latter method which has the advantage to allow a direct graphical comparison of the investment levels when the game is sequential and when the game is simultaneous. The same kind of trick can be used to solve the Stackelberg equilibrium where a leader and a follower compete in quantities to sell an homogenous product.

[8] Amir et alii (2001) show that the equilibrium R&D level is decreasing in the spillover parameter but, in their model, the parameter is defined at the production stage as information sharing to decrease costs while in our model the spillover parameters are shortcuts for all the interactions between firms at all stages.

3 Industry-specific Externalities

In this section we consider the innovation game in the industry of ICTs. We successively consider the four cases where η_E and η_I can be both positive, or both negative or can have opposite signs.

3.1 The Music Industry

We first consider the case where the follower benefits from the research of the innovator ($\eta_E > 0$) but the presence of the imitator is harmful to the innovator ($\eta_I < 0$). This case corresponds to the traditional model of imitation, where imitation (respectively innovation) creates a negative (respectively positive) externality on the innovator's profit (respectively the imitator's profit).

Because $\eta_I < 0$, when facing the threat of imitation we can see in Figure 1 that the innovator has a natural incentive to invest less than when there is no such threat ($x_I^* < x_I^m$). But this is the unconstrained equilibrium of the sequential game. As an innovator, firm I is protected against too large ($x_E \leq \overline{x}_E$) or too small investment ($x_E \geq \underline{x}_E$) of the challenger. Do these limits help the innovator to keep a high level of investment?

The requirement to invest at least $\underline{x}_E$ is binding only when $\underline{x}_E > x_E^*$. It has an adverse effect on the innovator's profit who is obliged to increase his R&D investment ($\widehat{x}_I(\underline{x}_E) > x_I^*$) at least as long as $\underline{x}_E$ is not too large. For a very large requirement $\underline{x}_E$, the effort of the incumbent is less than x_I^*. Actually, as can be seen in figure 1 and figure 2, when $x_E \geq \underline{x}_E$ is imposed, the R&D expenditure of the innovator expressed as a function of $\underline{x}_E$ is discontinuous at point x_E^*. This is because imposing such a constraint is like changing the timing of the game. The regulated value of the follower expenditure $\underline{x}_E$ is fixed before the innovator expenditure x_I.

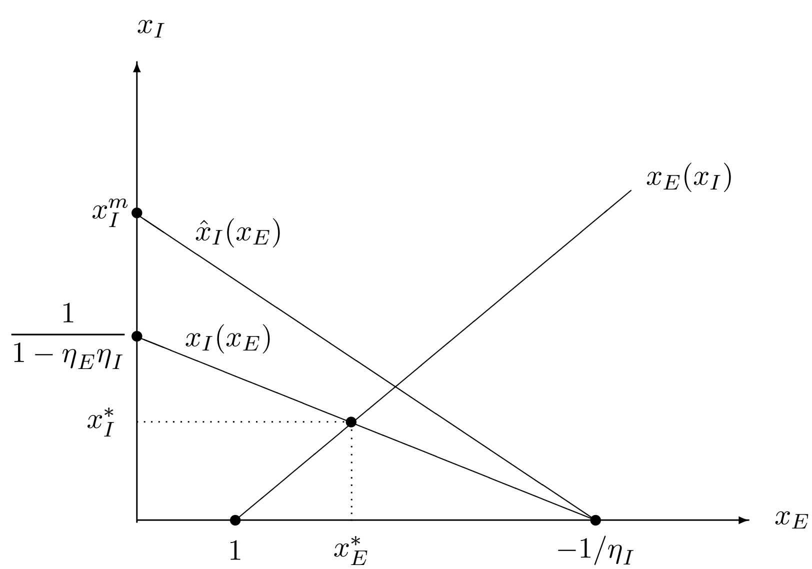

Figure 1: Research efforts in the music industry ($\eta_E > 0, \eta_I < 0$)

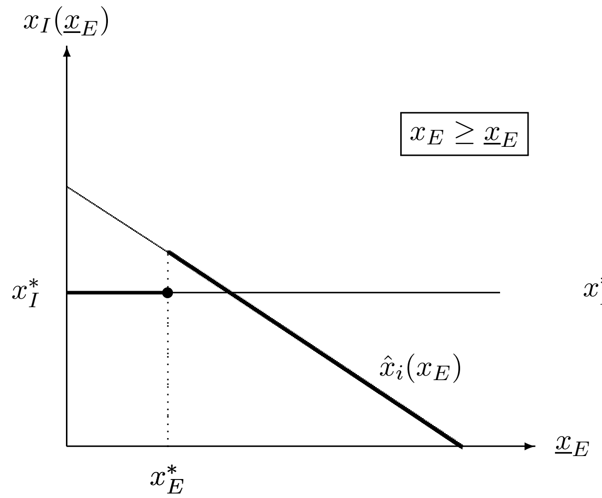

Figure 2: Effect of a minimum requirement on x_E for the innovation expenditures

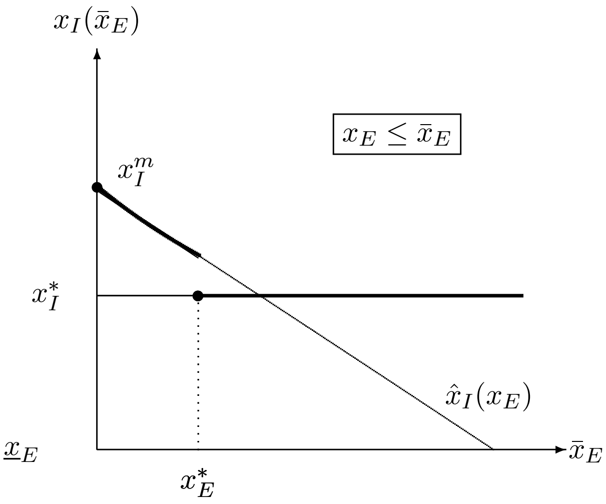

Figure 3: Effect of a maximum requirement on x_E for the innovation expenditures

Symmetrically, from figures 1 and 3 we see that the upper limit $x_E \leq \overline{x}_E$ has a positive effect on the investment of the innovator ($\widehat{x}_I(\underline{x}_E) > x_I^*$ for $\overline{x}_E < x_E^*$) but it cannot give the innovator an incentive to invest more than when there is no imitator at all ($\widehat{x}_I(\underline{x}_E) \leq x_I^m$).

This case is the benchmark for the defenders of intellectual property rights: all efforts by the innovator are good for imitators, whereas the former suffers from the activity of the latter.

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A very tough IPRs policy that prohibits entry (if, for instance, entry becomes prohibitively costly, i.e., $\underline{x}_E$ very large, or if entry is prohibited $\overline{x}_E = 0$) allows the innovator to invest at the monopoly level. This level is higher than what he would have invested if a very lenient IPRs policy was enforced (i.e., for $\underline{x}_E < x_E^*$) or even if the policy was tougher and entry was just restricted (for $\underline{x}_E > x_E^*$ but not too high). So, from the innovator's viewpoint, a very tough IPRs policy induces more innovation by preventing imitation. However, any IPRs policy that permits entry (restricted or not) allows to increase the total sum of the investments made by firms. Thus, from a strict society's viewpoint, it is not clear whether a very tough policy that completely prevents entry is better than a softer requirement that allows to speed up imitation, or eventually improvement. As long as the former innovator gets enough benefit to cover his investment, imitation may be beneficial to society.

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The music industry is a good illustration of this situation. At the beginning of 2000, Napster developed a program to download MP3 files. In less than six months the music industry *i*) incurred losses evaluated at $ 20m and *ii*) sued Napster at law to obtain the withdrawal of the program needed for downloading. Music companies argued that given the copy (imitation) activity encouraged by Napster-like firms, their expenditures in new talents research and recording activity would drop dramatically (say from x_I^m to x_I^*). The demand for withdrawal and the decision taken by courts in 2001 consist in the tentative to go back to x_I^m. Napster has now disappeared but it has been replaced by many newcomers.[9] From the figures, we see that if the public objective is to keep the effort of I as high as possible, the best policy is to fix $\overline{x}_E = 0$.

An innovation can also be severely damaged by dramatic improvements. All the history of the software industry is made of first movers excluded from the market by a drastically improved version of their product: Word, Excel, Explorer and Outlook have replaced respectively WordPerfect, Lotus 1-2-3, Netscape and Eudora as dominant applications.[10] This extreme case is illustrated by the case where η_I is close to -1. From (8) and (9) we see that this results in the bankruptcy of the innovator ($x_I^* \rightarrow 0$) and its replacement by the follower ($x_E^* \rightarrow 1 = x_E^m$). In this case, it would be inefficient to protect I.

3.2 The Software Industry

We now consider the case where the innovator benefits from the research of the follower, and, reciprocally, the follower benefits from the efforts of the innovator ($\eta_E > 0$ and $\eta_I > 0$). Following the 'conventional' definition of Bulow, Geanakoplos and Klemperer (1985), the investment decisions of the firms are strategic complements.

If the follower is allowed to freely enter the market the investment made by the innovator is non-ambiguously higher than the investment of the innovator when he is not threatened by any imitator: we see from figure 4 that $x_I^* > x_I^m$. In this case the expected presence of the follower boosts innovation: the innovator has high incentives to invest more since he will later benefit from the efforts of the follower.

Now if $x_E^* < \underline{x}_E$, we also have $x_I(\underline{x}_E) > x_I^m$ by transitivity.[11] But $x_I(\underline{x}_E)$ can be larger or smaller than x_I^* depending on the slopes of $\widehat{x}_I(x_E)$ and $x_I(x_E)$ and on the value of $\underline{x}_E$. If the minimum investment requirement $\underline{x}_E$ is larger than but close to x_E^*, we see that the R&D expenditure of the innovator is lower than without the $\underline{x}_E$ requirement.

Because of the discontinuity in the innovator's investment created by the legal restriction imposed to the follower ($x_E \geq \underline{x}_E$ or $x_E \leq \overline{x}_E$) if the government wants to foster R&D efforts

[9] See www.afternapster.com.

[10] The idea that the four Microsoft's products are technically better than their predecessors is developed in Leibowitz and Margolis (2001). Some authors challenge this idea and consider that Microsoft won the battle by its marketing policy (mainly forced bundling) rather than on technical grounds; see Gilbert and Katz (2001).

[11] As $x_I(x_E)$ is an increasing function. The reader can easily draw the graphs of $x_I(\underline{x}_E)$ and $x_I(\overline{x}_E)$ corresponding to figure 4 like we did with figures 2 and 3 that correspond to figure 1.

by imposing a minimal constraint on followers, this constraint is to be very stringent, namely $x_E \geq \widehat{x}_I^{-1}(x_I^*) = \frac{1+2\eta_E}{1-2\eta_E\eta_I}$. Clearly, a maximum requirement $x_E \leq \overline{x}_E$ would not be a good idea either since the effort of I is increasing with x_E. At most, the innovator will invest x_I^*. At worst (when $\overline{x}_E < x_E^*$), he will invest $\widehat{x}_I(\overline{x}_E) < x_I^*$.

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A very tough IPRs policy has a negative impact on investments as a monopoly always invests less than competitive firms. In this case it is clear that competition boosts innovation. Furthermore, the total sum of investments is always higher under IPRs policies that allow entry.

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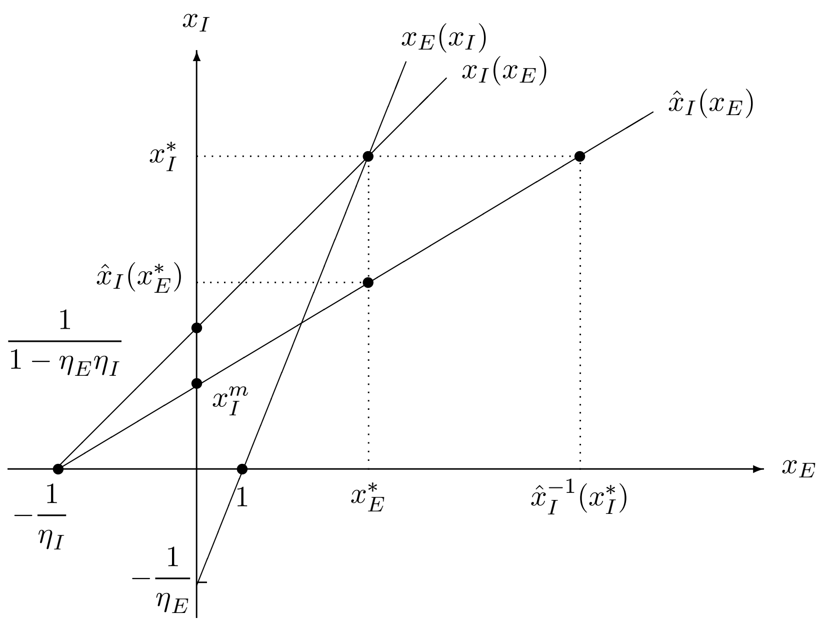

Figure 4: Research efforts in the software industry ($\eta_E > 0, \eta_I > 0$)

This parameter configuration can be observed in the software industry where developers of operating systems (OS) benefit from the expenditures of applications' publishers ($\eta_I > 0$) and symmetrically, the applications' publishers benefit from the financial effort of the OS developers ($\eta_E > 0$). Consequently if we just want to increase the OS research expenditure, it is better not to impose any minimum constraint on the effort of the applications' publishers if it is a mild constraint. Indeed a constraint $x_E \geq \underline{x}_E$ where $\underline{x}_E$ is slightly above x_E^* would have the adverse effect of decreasing x_I. Alternative solutions to increase x_I are to encourage joint venture and to organize a merger between the OS and application producers as we will see in section 4. But the simplest obvious to policy is to leave this type of industry without any restriction to the entrant's decisions.

3.3 The Hardware Industry

Consider now that the follower does not benefit from the innovator ($\eta_E < 0$) while the latter benefits from the entrant's effort ($\eta_I > 0$).

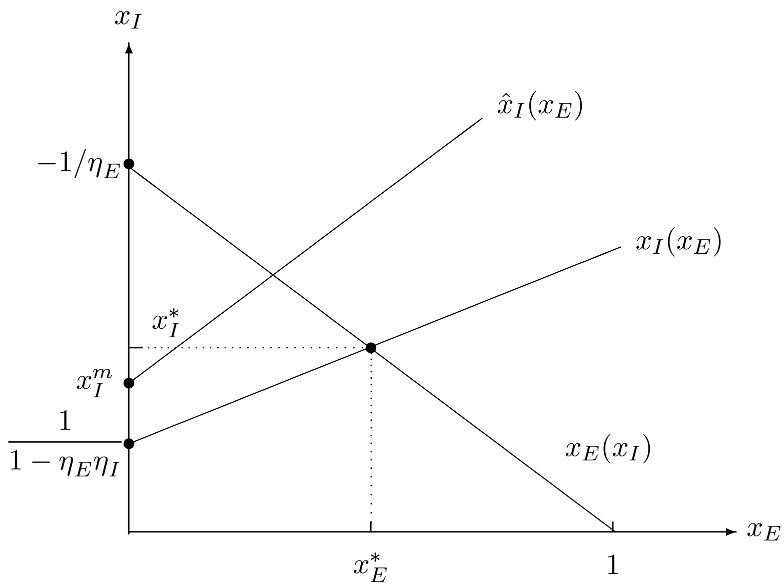

Figure 5: Research efforts in the hardware industry ($\eta_E < 0, \eta_I > 0$)

Because of the negative externality they suffer from the innovator ($\eta_E < 0$), the follower is somewhat reluctant to invest. By contrast, the innovator would like her to increase her research efforts. A minimal requirement $x_E \geq \underline{x}_E$ above x_E^* is a good incentive to develop the innovator's effort since $\widehat{x}_I(\underline{x}_E) > x_I^m$ for all $\underline{x}_E > x_E^*$.

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An IPRs policy that prevents entry induces the innovator to invest more only if the negative externality of the follower is very large (i.e., $\eta_E < -0.5$). Otherwise, competition tends to boost innovation. For any value of the spillovers, the total sum of investment is always higher under competition than if it prohibited. However, a policy that restricts entry (i.e., $\underline{x}_E > x_E^*$) allows to increase the investment of the innovator as well as the total sum of the investments.

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In industries with strong network externalities, innovators benefit from a large users base. They face a trade-off to let imitators enter. On one hand, they benefit from additional users but, on the other hand, they lose in unit sales. A good example is the hardware industry where innovators (brand firms) may have advantage in letting "clones" be in the market. For instance Sun Microsystem, has encouraged clones of its computer workstation to build its technology's user base (Conner (1995)). Those consumers who favour higher quality, have a preference for the branded hardware. As the innovator invests in providing cheaper computer workstations, the demand for clones decreases and thus it hurts the imitator ($\eta_E < 0$). On the other hand, the introduction of clones allows the user base to grow, so the innovator gains from letting the imitator be in the market ($\eta_I > 0$). Thus imitation boosts innovation. It is even more dramatic if the imitation is restricted: the innovator invests more than without the minimum or maximum requirement imposed to the imitator.

3.4 The Video Game Industry

In many industries, the follower suffers from the innovator ($\eta_E < 0$) and the latter suffers from the former ($\eta_I < 0$). In this case, the investment decisions of the two firms are strategic substitutes.

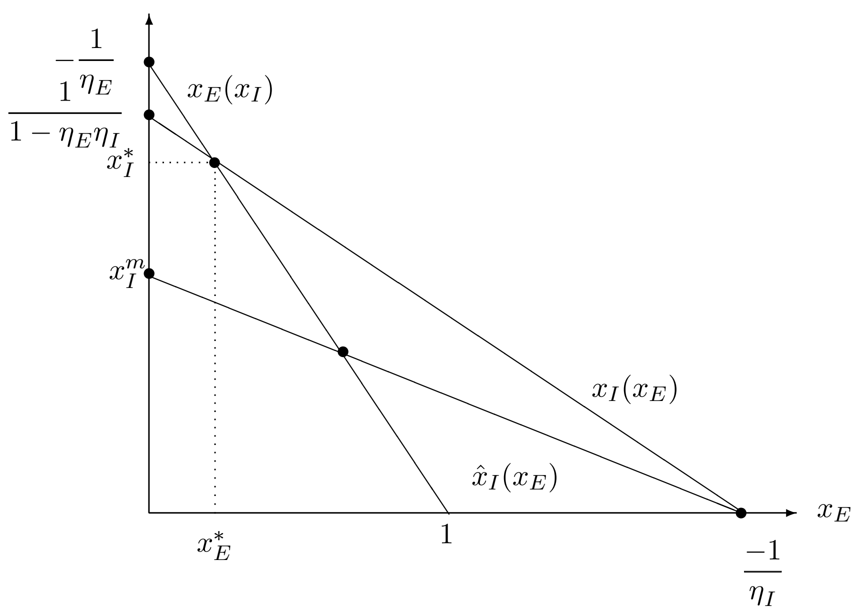

Figure 6: Research efforts in the video-game industry ($\eta_E < 0, \eta_I < 0$)

As compared with the case where the innovator does not suffer from any imitation ($\eta_I = 0$ and thus $x_I^* = x_I^m$), when $\eta_I < 0$ we see that the presence of the imitator has the effect to increase (respectively decrease the innovator's effort) as $\eta_E < -1/2$ (respectively $\eta_E > -1/2$).

Once more, the introduction of a minimum requirement on x_E has the effect to create a downward jump in x_I at point x_E^*. But contrary to the former case, an additional increase in $\underline{x}_E$ provokes a decrease in $x_I(\underline{x}_E)$. Therefore, to fix a minimal threshold for the investment by imitators is always detrimental for the efforts of the innovator.

When η_E is very small ($\eta_E < -1/2$), the innovator is inclined to overinvesting ($x_I^* > x_I^m$) because she knows that this is armful to imitators who will invest less. Consequently, if the government fixes $\underline{x}_E > x_E^*$, this dissuasive policy does not work any longer. On the contrary, we observe that $x_I(\underline{x}_E)$ is less than x_I^m for $\underline{x}_E > x_E^*$. The requirement $\underline{x}_E$ that can be viewed as the investment that measures the novelty of an improvement on the initial innovation provides a negative incentive to innovate. The higher $\underline{x}_E$, the lower is the incentive to spend money on the initial innovation: $\underline{x}_E$ is like a barrier that protects the innovator.

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Thus, a tough IPRs policy allows the innovator to invest more only if the follower's negative externality is very strong ($\eta_E < -1/2$). When entry is just restricted, the innovator does not invest more. Here again competition induces firms to investment more compared to what a monopoly would do.

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In industries where the leader and the follower have different standards, the more the leader invests in an innovation that promotes his standards, the less the follower benefits from it ($\eta_E < 0$). On the other hand, the more the follower invests in an innovation that is compatible with her own standard, the lower the profit of the leader ($\eta_I < 0$). Innovators invest more in presence of competitors. The competition between Nintendo and Sega is relevant for this specific case. Indeed, every time Nintendo invents a new game, Sega loses consumers. Then Sega invests to produce a similar-kind of game that will be detrimental to Nintendo.[12] If the government intervenes and forces Sega to artificially differentiate its product for instance, it will reduce innovations, instead of boosting them. In fact each firm will compete in different markets.

The present fight for digital dominance between Microsoft and Nokia in the mobile phones market is another illustration of this case of technological competition.[13]

[12] Concerning the study of standards as well as the competition between Nintendo and Sega, see Shapiro and Varian (1999).

[13] See The Economist, November 21, 2002.

4 The internalization of spillovers[14]

In the innovation game, each player in his turn appears as the leader.[15] The strategies are so intricate that the game is a complex combination of simultaneous, sequential and collusive behaviors. Each player should also take into account the likelihood of positive and negative externalities. In the short run, the sign of the spillover coefficients can be forecast reasonably well but in the medium run it is much harder. An additional reason is that all actual candidates to innovation and innovators are simultaneously facing actual and would-be providers of complement and substitute products, not just one like in our model. The incentives to integrate horizontally and vertically and to take the control of ally or competitor start-ups are driven by the sake of internalization. For example, in November 2002, Comcast (a cable operator) merged with AT&T Broadband to create a giant of the US media and communication industry (22m subscribers). The objective of the merger is to stop customers leaving: during the nine first months of 2002, some 0.6m left (most of them from AT&T Broadband) to satellite TV which is cheaper. Joining the efforts of the two companies would eventually allow to diversify into activities more profitable than cable TV broadcasting and to propose services that satellite rivals cannot match, namely broadband internet access, interactive television and national cable-telephone.[16]

The spillover effect at work in the former sections can have several origins and different materializations: technological, legal, marketing.[17]

[To be completed]

[14] For a survey on R&D cooperation, see DeBondt (1997).

[15] "Sony, the world's largest consumer-electronics maker is under constant assault from a host of new competitors, with Samsung leading the pack. The one clear advantage Sony has had is its strong brand image, which is still the global electronics brand to beat. But now, that edge is being blunted.(...). Samsung has quickly gained technical prowess and is learning the Sony-pioneered art of turning gadgets into fashion accessories. Now it is building a brand. In 2002, Samsung has spent more than $900 million world-wide on branding activities such as television ads and retail promotions, compared with $700 million last year."

Sony must now "introduce new products first in markets where Samsung is strongest," says Sony President Kunitake Ando. "They've learned so much from us. ... Now they're becoming a much bigger influence on our strategy". From the Wall Street Journal Europe, December 20-22, 2002.

[16] Additionally, "Comcast has a foot in the content business through the QVC home shopping channel, its Hello!-style entertainment channel, E!, and the Golf Channel. Its latest project is G4, a channel for video games. With its enlarged customer base, Comcast will become a powerful partner for those looking to launch new services. 'The beauty of having 21.5m customers is for ourselves or other companies or entrepreneurs to enable their business plans,' Mr Robert (the Comcast's president) says." From the Financial Times, December 20, 2002.

[17] In d'Aspremont and Jacquemin (1988), knowledge spills over after the end of the R&D process, i.e., spillover relates to R&D outputs. By contrast, in Kamien et al. (1992) knowledge spills over during the R&D process, i.e., spillover relates to R&D inputs. In our model, we cannot distinguish between the two types of spillover.

Like in many other sequential decision processes, the participants to the innovation game suffer sort of intertemporal schizophrenia. When they are candidates to entry they would like to face doors wide open. Later, the winners of the race will argue that doors should be kept tightly closed. Let us remain within our model where the decision variables are investment in R&D, not legal arrangements that are exogenous. Because of the aforementioned evolution of the players' interests a complete description of the innovation game should require that entrants internalize their expected behavior as future incumbent. If they do so, their objective is to maximize $V_E(x_E, x_I) + \rho V_I(x_E, x_I)$ where ρ stands for both the discount factor and the probability to be the next incumbent. Such a forward-looking entrant facing no competition (except herself in the future) would choose to invest today up to

$$x_E^f = 1 + \frac{(\eta_E + \rho\eta_I)(\rho + \eta_E + \eta_I)}{\rho - (\eta_E + \rho\eta_I)^2}$$

which internalizes the future spillover of her today decisions as well as the effects of the future decisions on the profits from the today decisions. With perfect internalization ($\rho = 1$), we obtain a today's investment

$$x_E^f = \frac{1}{1 - (\eta_E + \eta_I)}$$

where the only thing that matters is the net value of the spillover coefficients $\eta_E + \eta_I$.

If the entrant perfectly internalizes her future status, she is behaving like if a joint venture. It can be the case that spillovers compensate each other, so that $x_E^f = 1$ when they have opposite signs. But when they have the same sign, they induce either a greater effort when the two activities are complements (η_E and η_I positive) or a smaller effort when they are substitute (η_E and η_I negative).

In a perfect joint venture, it is easy to check that the present investment of each partner is[18]

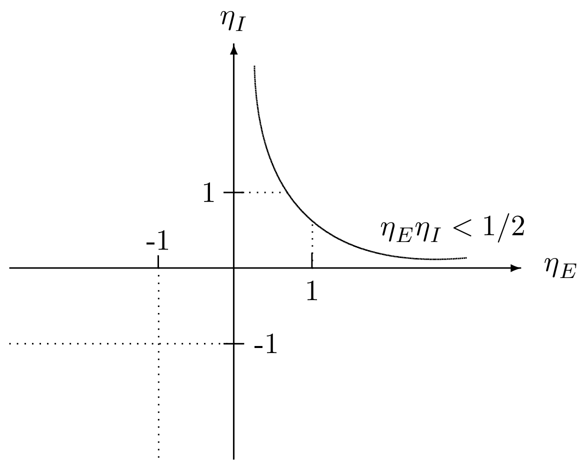
$$x_E^f = x_I^f = \frac{1}{1 - (\eta_E + \eta_I)}$$

How does the total R&D expenditure $x_E^f + x_I^f$ compare with the total effort in the leader-follower game? Using (8) and (9), we can establish that

$$sign\left\{x_E^f + x_I^f - (x_E^* + x_I^*)\right\} \equiv sign\left\{\eta_I(1+\eta_I) + \eta_E(1+\eta_E) - \eta_I\eta_E(1+\eta_E+\eta_I\right\}$$

[18] Actually, in the literature on cooperative research, the standard hypothesis is that the spillover coefficients are higher when firms cooperate (the coefficients are indices of ("information exchange") than when they do not cooperate ("information leakage"). See for example Katz (1986), Motta (1992).

If both parameters are negative (and less than 1 in absolute value), the effect of the joint venture is to decrease the total effort. If they are positive (and $\eta_E \eta_I < 1/2$) the total effort is increased[19]. The sign is not clearly established in all the other cases.



One case where the net value of the spillover coefficients of each firm (taking into account all the positive and negative externalities resulting from technological constraints and market conditions) is most likely positive is when firms have to decide on an industry-wide standard.

For example, since 1999, hundreds of firms in the telecom industry support Voice XML (for Voice eXtensible Mark-up Language) as a common language for all the voice applications. Nowadays, when we want to obtain traffic information or to check bank accounts by phone without the intervention of a live operator, we are limited to pushing some buttons or using a predefined vocabulary. These flaws obviously impair the profitability of this type of activity. To develop it necessitates drastic progress in speech recognition. This is the objective of the Voice XML, pushed by the main firms of the telecom industry within World Wide Web Consortium (W3C), an Internet standards body.[20] The industry members all expect lower costs (saving on live operators) and higher demand (due to easier and more rapid information).

[19] This is the case usually analyzed in the economic literature, in particular by d'Aspremont and Jacquemin (1988).

[20] See the Economist, December 14, 2002, p. 28-29. In the past, W3C developed HTML (for Hypertext Mark-up Language) used to design web pages.

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