E C O N O M I C S B U L L E T I N

A note on duplication of RDand RDsubsidies

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Abstract

We show that the presumed incompatibility of uncoordinated RDand competition is not fundamental, but hinges on the nature of RDspillovers. As a consequence, RDsubsidies may be more effective than previously thought.

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1 Introduction

The economics of R&D offer a congregation point for most forms of market imperfections, be they large fixed costs, uncertainty, or externalities. The design of optimal policies thus turns into a challenging exercise. In particular, the conflict between marginal cost pricing and the free-rider problem associated with R&D spillovers calls for a policy that can restore the firms' incentives to engage in R&D, while simultaneously maintaining a competitive environment.

In a seminal paper, Spence (1984) showed that when firms independently invest in R&D, social welfare eventually decreases as the number of firms increases. Intuitively, this important result is driven by the interaction of three effects: while competition increases with the number of firms and forces firms to price closer to marginal cost, losses attributable to both free-riding on other firms' R&D and duplication of R&D efforts increase.

He also showed that firms' *incentives* to undertake R&D could be fully restored through appropriate R&D subsidies. Surprisingly, however, because losses due to duplication *alone* can outgrow the benefits from increased competition, his result continues to hold even when optimal R&D subsidies eliminate free-riding behavior. This result suggests a fundamental incompatibility between R&D and a competitive environment when firms are not allowed to *coordinate* their R&D efforts.

In light of the presumed incompatibility between independent, uncoordinated R&D and a competitive environment, and in the wake of Spence's seminal paper, alternative solutions *combining* competition in the product market with cooperation in the R&D sector have been proposed. These solutions to the externality problems associated with R&D, such as R&D cooperative agreements or Research Joint Ventures (RJV), have been pioneered by the seminal works of d'Aspremont and Jacquemin (1988) and Kamien, Muller, and Zang (1992).[1] In this literature, firms invest in R&D in a first stage and engage in Cournot or Bertrand competition is a second stage. Whereas R&D coordination alleviates free-riding by internalizing externalities, RJVs have the additional benefit of solving the duplication problem, because members fully share the results of R&D.

Since they simultaneously solve all three problems, namely allocative ef-

[1] The large subsequent literature includes Vonortas (1994), Martin (1996, 2002), Leahy and Neary (1997), Amir and Wooders (1988), and Amir, Evstigneev, and Wooders (2003). For excellent surveys, see De Bondt (1997) and Martin and Scott (1998).

ficiency, free-riding, and duplication, RJVs would *appear* to unambiguously dominate Spence's subsidy-based solution. However, Hinloopen (1997, 2000) shows that in the case of symmetric *duopolies,* the subsidization of non-cooperative R&D is more effective than R&D cartels or RJVs. Still, in light of Spence's result, it is not clear whether Hinloopen's finding would continue to hold as the number of firms —and the related duplication problem— increases. In this paper, we show that the purported incompatibility between R&D and a competitive environment is not fundamental, but hinges on the nature of the R&D technology.

Amir (2000) showed that the modeling choices for R&D processes used in the literature fall into two categories: either –as is the case in Spence– spillovers are in R&D *input* (or R&D investments), or they are in R&D *output* (or knowledge created) as in d'Aspremont and Jacquemin (1988). We show that if spillovers are in output, rather than in input, the inefficiency associated with duplication of R&D effort unambiguously *decreases* with the number of firms. As a consequence, a subsidy-based policy can fully solve the externality problems associated with R&D.

2 The Main Result

We show here that Spence's result, namely that as the number of firms increases, the losses from duplication eventually outweigh the gains from allocative efficiency, hinges on the choice of R&D technology.[2]

More formally, let the constant marginal cost of production for each firm be given by

$$c = A - r(x, n, \beta), \tag{1}$$

where A is the constant marginal cost of production in the absence of R&D and where the amount of cost-reduction r is a function of the amount of R&D investment x, the number of firms n, and the R&D spillover parameter β $(0 \leq \beta \leq 1)$.

Suppose then that x dollars are to be allocated equally among the n independent research labs. Under input-side spillovers, the cost-reduction

[2]It is important to note that we are working in the context of optimal subsidies with a fully alleviated free-rider problem.

function can be written as

$$r(x, n, \beta) = f\left(\frac{x}{n} + \beta(n-1)\frac{x}{n}\right) = f\left(\frac{1+\beta(n-1)}{n}x\right), \tag{2}$$

where the R&D production function f is assumed to be both increasing and concave, reflecting diminishing returns to R&D expenditures. Clearly, $r(x, n, \beta)$ is decreasing in n. The efficiency with which an industry thus achieves a certain amount of cost reduction decreases with the number of firms.

If, on the other hand, spillovers are in R&D *output*, then each firm's cost reduction function can be written[3]

$$r = f\left(\frac{x}{n}\right) + \beta(n-1)f\left(\frac{x}{n}\right). \tag{3}$$

It is now straightforward to show that $\frac{dr}{dn} > 0$ if

$$\frac{f(x/n)}{x/n} > \left(\frac{1+\beta(n-1)}{\beta n}\right) f'(x/n), \tag{4}$$

which reduces to

$$\frac{f(x/n)}{x/n} > f'(x/n) \tag{5}$$

as $n \to \infty$. Since f is concave, inequality (5) is satisfied for n sufficiently large. Note that for some specific functions, inequality (4) may even hold for all n. For example, if $f(\cdot) = \sqrt{\cdot}$, as in d'Aspremont and Jacquemin's original model, it is easy to show that inequality (4) will be satisfied as long as $\beta > 1/(1+n)$.

We therefore conclude that, provided spillovers in R&D output are not too small, the efficiency with which an industry achieves a certain amount of cost reduction *increases* with n. Since allocative efficiency increases with n as well, market performance unambiguously improves.

[3] We justify this expression as follows: Simply let the cost of an amount y_i of R&D undertaken by firm i be $C(y_i)$, with C strictly convex and $C(0) = 0$, and define $f(\cdot) \equiv C^{-1}(\cdot)$. If $x_i \equiv C(y_i)$ denotes the amount of *dollars* invested in R&D by firm i, then firm i's cost reduction can be written as $r_i = f(x_i) + \beta f(x_j)$, where f is strictly concave since C is strictly convex. For example, if $C(y_i) = y_i^2 \equiv x_i$, as d'Aspremont and Jacquemin (1988) assumed, we obtain $r_i = \sqrt{x_i} + \beta\sqrt{x_j}$.

3 Conclusion

We showed that even though both technologies exhibit diminishing returns to R&D expenditures, they lead to diametrically opposite policy implications. If spillovers are in R&D output, the incompatibility between competition and uncoordinated R&D disappears, performance unambiguously improves with the number of firms, and Spence's subsidy-based solution becomes a viable alternative to Research Joint Ventures.

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