Abstract

I consider the implications of recent research for R&D policy in developing countries. Typical new growth models, which assume free entry and no strategic behaviour by R&D producers, are less appropriate for policy guidance than strategic oligopoly models. But the latter have ambiguous implications for targeted R&D subsidies, and caution against the anti-competitive effects of research joint ventures. A better policy is to raise the economy-wide level of research expertise. This avoids the need for governments to pick winners, is less prone to capture, and dilutes the strategic disincentive to undertake R&D with unappropriable spillovers.

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R&D in Developing Countries:
What Should Governments Do?

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Introduction

Differences in technological knowledge, broadly defined, are clearly one of the principal explanations of the enormous variation in living standards between countries. Hence, policies to encourage research and development might be expected to play a central role in programs designed to combat underdevelopment. Yet, notwithstanding the huge amount of research done on R&D, the complexity of the topic means that the issues are far from fully understood and the challenge to design appropriate policies remains considerable. It is commonplace to label the Solow residual, the portion of output growth not explained by factor accumulation, as 'total factor productivity', but the label itself suggests some understanding of the concept. An older label, the 'coefficient of ignorance', may be more appropriate given our present state of knowledge.

One field which considers R&D in detail is the theory of endogenous growth.[1] However, the assumptions made about industrial structure and firm behaviour in that literature seem unattractive in the context of discussions of policy design. R&D is typically assumed to be carried out by different firms from those engaged in production. Moreover, notwithstanding the complexities of the models in other respects, equilibrium is typically assumed to be monopolistically competitive, so firms do not engage in strategic behaviour, and entry into the industry is free. For many purposes these assumptions are not a drawback. For designing optimal policies towards R&D they seem less appropriate.

In this paper I review some of the results in an emerging literature which examines the determinants of R&D in a different framework, one in which barriers to entry, multi-stage competition and strategic behaviour are central features. This literature draws on the theories of international trade and industrial organisation, and in particular on the theory of strategic trade policy which developed in the 1980s. I begin by considering its implications for R&D subsidies.

2. Strategic R&D Subsidies

What does the theory of strategic trade policy imply for R&D subsidies? Recall first the basic result of the theory for optimal export subsidies in the simple static case with no R&D.[2] There are two firms, one domestic and one foreign, producing goods which are close substitutes. The home government does not care about consumers (perhaps because all home output is exported). Then it can use its superior commitment power (or 'first-mover advantage') to move the foreign firm along its reaction function by subsidising or taxing the home firm's output. There is an unambiguous welfare gain (where welfare is just home profits before tax or subsidy payments). But the actual policy prescription is highly ambiguous, depending on the nature of competition between the firms. If they choose quantities, so competition is of the Cournot type, then the optimal

[1] See, for example, Aghion and Howitt (1998) and Grossman and Helpman (1991).

[2] Brander (1995) gives a detailed survey and extensive references.

policy is an export subsidy; whereas if they choose prices, so competition is of the Bertrand type, then the optimal policy is an export tax.[3]

Now add prior investments in R&D to this model. There is some level of R&D (in general a function of outputs or prices) which equates its marginal cost to its marginal return. Call this the 'efficient' level of R&D. In the absence of policy, each firm has an incentive to diverge from this efficient level, in a manner vividly described by the 'animal spirits' taxonomy of Fudenberg and Tirole (1984); and once again the nature of competition between the firms is crucial since it determines the direction of divergence. If competition is Cournot, then each firm has an incentive to behave like a 'top dog', *over*-investing relative to the efficient level in order to push its rival *down* its output reaction function, and enjoy higher output and profits at its expense. While if competition is Bertrand, then each firm has an incentive to behave like a 'puppy dog', *under*-investing relative to the efficient level in order to push its rival *up* its price reaction function, so that both firms enjoy higher prices and profits.[4]

What is the optimal policy package in this case? It turns out that there is a natural division of labour between the optimal R&D subsidy and the optimal export subsidy. Essentially, R&D policy should be targeted towards restoring R&D efficiency, whereas trade policy should be targeted towards manipulating the foreign firm. The latter implies a policy identical to the static model: an export subsidy if competition is Cournot, an export tax if it is Bertrand. The former leads to an 'animal training' taxonomy. If competition is Cournot then R&D should be taxed: the top dog should be 'restrained' from socially wasteful over-investment. Conversely, if competition is Bertrand then R&D should be subsidised: the puppy dog should be 'encouraged' to desist from under-investment. To sum up, adding prior investments in R&D to this model compounds rather than reduces the ambiguity about the sign of policy which we found in the static case.[5]

One possible resolution to this ambiguity has been proposed by Brander (1995). This focuses on the case where export subsidies and taxes cannot be imposed, perhaps (realistically) because they are outlawed by international agreements. Brander notes that for this case a number of different authors have found that the optimal investment subsidy is positive irrespective of whether competition is Cournot or Bertrand, and he conjectures from this that R&D subsidies may be more robust than export subsidies as strategic policy tools.[6] However, Neary and Leahy (2000)

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[3] To be more specific, the optimal subsidy is positive if the foreign firm's action is a 'strategic substitute' for the home firm's, meaning that an increase in the foreign firm's action lowers the marginal profitability of the home firm's. This is equivalent to downward-sloping reaction functions, the normal case in Cournot competition, just as upward-sloping reaction functions (or strategic complementarity) is the normal case in Bertrand competition.

[4] In behaving like this, the firms are essentially behaving just like the government in the static games of the previous paragraph: exercising their ability to pre-commit in order to influence in their favour the outcome of the output or price game. There is one crucial difference, however. Strategic investments by firms consume real resources, whereas government intervention does not (unless there are deadweight losses from financing subsidies, as in Neary,1994). That is why it is welfare-improving for the home government to take over the pre-commitment role from the home firm.

[5] These results for the Cournot case were first obtained by Spencer and Brander (1983). The general case is considered in Neary (1999, Section IV) and Neary and Leahy (2000).

[6] The findings of Maggi (1996) give further support for this result. Building on Kreps and Scheinkman (1983), he considers only Bertrand competition, but uses a particular specification of costs such that the outcome of the two-stage game mimics that of a one-stage game, either Cournot or Bertrand depending on parameter values. He also finds that an investment subsidy is always optimal when export subsidies are unavailable.

point out that this is only a second-best argument. With trade policy ruled out, the R&D subsidy has to perform two distinct roles: both to offset inefficient investment and to act as a surrogate for the unavailable export subsidy or tax. As with all second-best results, the optimal policy is likely to be sensitive to the assumptions made about functional forms. Under a benchmark linear-quadratic specification, the optimal R&D subsidy is always positive, but simulations suggest that the welfare gain from intervention is extremely small (much less than in the case where both R&D and export subsidies can be offered, which itself yields only modest welfare gains relative to non-intervention).

So far, the lessons of this literature for practical policy-making seem to be limited. However, the last point suggests a more positive final observation. There is considerable evidence, from both theoretical simulations and empirical calibration exercises, that the gains from optimal strategic policies are small. On the other hand, much recent work suggests that the losses from sub-optimal policies may be large if governments cannot commit in advance to future policies.[7] The problem which arises is that firms exploit the government's inability to commit by engaging in inefficient investment in order to influence the export subsidy which they anticipate in later periods.[8] All this shows clearly the advantages of a stable policy environment. By analogy with arguments well known in the macroeconomic context, commitment to future subsidy programs (even if the precise policies themselves are sub-optimal) yields higher welfare than allowing subsidy programs to be manipulated by firms.

3. R&D Spillovers and Research Joint Ventures (RJV's)

Until now I have assumed that R&D is a purely private good, so all its benefits are appropriable by the firm which undertakes it. Obviously this ignores one of the primary features of R&D, so suppose instead that R&D generates spillovers for other firms. A standard way of modelling this, in both theoretical and empirical work, is to assume that the marginal cost of production of each firm in a given industry depends negatively on both its own and its rivals' R&D, denoted by x and X respectively:[9]

$$c = c(x+\beta X), \qquad c' < 0, \qquad 0 \leq \beta \leq 1 \tag{1}$$

Here, β is the spillover parameter, which for the moment I take to be exogenous. A key result, which goes back at least to Arrow (1971), is that higher values of β reduce the incentive to engage in R&D. As with any public good, the inability to appropriate all the benefits of R&D leads private firms to under-provide it from a social point of view and, in principle, justifies subsidising

[7] See, for example, Goldberg (1995), Karp and Perloff (1995), Leahy and Neary (1996), Grossman and Maggi (1998), and Neary and O'Sullivan (1999). Leahy and Neary (1999b) show how these losses can be minimised by adjusting policies at early stages to compensate for the inability to pre-commit to policies at later stages.

[8] Note that the issue is not a simple choice between rules and discretion: it is precisely because the export subsidy rate is determined by a rule that firms are able to influence it by prior decisions on R&D. Either discretion or commitment to a long-term rule (ie, one set before R&D decisions are taken) would be preferable, though of course the former would be more vulnerable to lobbying.

[9] By contrast, Muniagurria and Singh (1997) assume that rival R&D lowers the direct costs of own R&D rather than lowering marginal production costs for a given level of own R&D.

it.

However, the issues discussed in Section 1 remain relevant even when we allow for R&D spillovers. The desire to encourage spillovers coincides with the strategic motive for intervention when competition is Bertrand, but conflicts with it in Cournot competition, although for sufficiently high spillovers the optimal subsidy is positive.[10] A further consideration is that the case for subsidisation is independent of whether the spillovers are national or international. As Leahy and Neary (1999a) note, this can lead to some surprising results. High spillovers mandate R&D subsidies even if the beneficiaries are foreign, not because the home government cares about foreign profits but because it wishes to offset the negative disincentives to investment arising from non-appropriability.

Two other practical difficulties arise with direct assistance to R&D. First, it is extremely hard to identify what kinds of spending should be classified as spending on R&D, except in the unrealistic case mentioned in the introduction where R&D and production activities are carried out by different firms. R&D subsidies give firms incentives to categorise as R&D all types of spending on fixed costs, and so they risk becoming merely generalised capital subsidies. Second, because of the fear of capture, the desire to minimise discretion, or budgetary constraints, it is often thought preferable to encourage R&D through tax concessions rather than direct subsidies. Paradoxically, this implies that *high-tax* rather than low-tax countries are at an advantage in competing for the location of R&D facilities. However, this conflicts with the fact that, in order to acquire a reputation for being well disposed to private enterprise, a developing country will typically want to aim for a low overall level of business taxes. Of course, this is just a reflection of the general point that poorer countries have a comparative advantage in production and assembly rather than in ‘headquarter services’ such as R&D.

An alternative route to combating the negative effects of R&D spillovers is to encourage firms to cooperate in R&D rather than to compete, through the formation of research joint ventures (RJV's). In principle, these internalise the R&D externality without the negative effects on product-market competition of a full merger. Since the work of d'Aspremont and Jacquemin (1988), an extensive literature has shown that RJV's raise welfare, especially if spillovers are high. They can also encourage information sharing, raising endogenously the value of β, an aspect stressed by Kamien, Muller and Zang (1992).

However, RJV's are not without difficulties. As Leahy and Neary (1997) point out, they can act as a surrogate for anti-competitive behaviour. Even though firms do not explicitly collude at the output stage, coordinating their R&D decisions gives them an opportunity to behave strategically in a manner which leads to sub-optimal levels of output. As a result, the payoff from encouraging RJV's is likely to be low and the welfare cost of lax competition policy is likely to be high, even when spillovers are high. A further point made by Leahy and Neary (1997) is that industry profits are *always* higher when firms choose their R&D cooperatively, the more so the higher are spillovers. So, intervention to encourage cooperation (or to facilitate it by relaxing anti-trust legislation), is likely to be least needed when cooperation itself is socially desirable. Of course, these results are not relevant to RJV's (whether exclusively domestic or between domestic firms and foreign multinationals) if the resulting output is to be exported. However, they are extremely relevant to the case of production for the home market.

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[10] d'Aspremont and Jacquemin (1988) showed that the threshold value of β equals ½ when competition is Cournot and demands are linear. Leahy and Neary (1997, Propositions 1 and 7) show that in general the threshold value is positive if and only if rival firms' actions are strategic substitutes for each other, and must lie between zero and one in Cournot competition with homogeneous products.

4. Absorptive Capacity

In addition to raising productivity directly, R&D also improves a firm's 'absorptive capacity', its ability to benefit from spillovers both from rival firms and from outside the industry. This view was first put forward by Cohen and Levinthal (1989), and in this section I consider some of its implications for public policy, drawing on work in progress by Dermot Leahy and myself (Leahy and Neary (1999c)).[11]

A simple but general way to model absorptive capacity is to replace (1) by:

$$c = \tilde{c}(x + \tilde{\beta} y) \qquad \text{where:} \qquad y = y(\underset{+}{x}, \underset{+}{X}) \tag{2}$$

As before, marginal cost is decreasing in the total R&D available to the firm. The novel feature is that a firm's ability to access the results of other firms' R&D depends on its own investment. Once again, X is the *actual* level of R&D carried out by other firms in the industry, but now it differs from y, the level of *usable* rival R&D. It is only usable R&D which gives rise to spillovers, and y is less than X. Usable R&D is increasing in both arguments, though it rises less than one-for-one with rival R&D: *i.e.* $y_x \geq 0$ and $0 \leq y_X \leq 1$.

To see the implications of this approach, combine the two parts of equation (2) into a reduced-form marginal cost function:

$$c(x,X) \equiv \tilde{c}[x + \tilde{\beta} y(x,X)] \tag{3}$$

Now, we can define an *effective* spillover parameter, which gives the ratio of the marginal returns to rival and own R&D:

$$\beta \equiv \frac{c_X}{c_x} = \frac{\tilde{\beta} y_X}{1 + \tilde{\beta} y_x} \tag{4}$$

The key result is that β is *less* than the direct spillover parameter $\tilde{\beta}$.[12] Expenditure on R&D has an added payoff because it is needed to avail of spillovers from rivals' R&D. This in turn has crucial implications for the arguments given in the previous section. Absorptive capacity dilutes the strategic disincentive to engage in R&D that generates spillovers which benefit rival firms. Hence it *reduces* the case for subsidising R&D.

A final implication of the absorptive capacity perspective concerns the role of knowledge from outside the industry. It seems plausible that in this case too the firm must engage in R&D before it can benefit from such knowledge. This suggests replacing equation (2) by:

$$c = \tilde{c}(x + \tilde{\beta} y, k) \qquad \text{where:} \qquad k = k(\underset{+}{x}, \underset{+}{K}) \tag{5}$$

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[11] See also Kamien and Zang (1997).

[12] To be precise, β cannot be *more* than the direct parameter $\tilde{\beta}$: $\beta \leq \tilde{\beta}$, with a strict inequality for either $y_X < 1$ or $y_x > 0$.

Here, *K* and *k* denote the levels of *actual* and *usable* extra-industry knowledge respectively. It can be checked that the effective spillover parameter $ is now further reduced. Increasing external knowledge has an extra strategic effect, which dilutes the disincentive to refrain from investment which will benefit competitors. The policy message is clear. Measures to raise the general level of research expertise in the economy are in any case likely to be superior to direct subsidies to the extent that they avoid the need for governments to pick winners and are less prone to capture. Our result shows that they have the additional advantage of diluting the strategic disincentive to engage in research with unappropriable spillovers.

5. Conclusion

In this short paper I have had space only to review some of the results in the emerging literature on strategic trade and industrial policy. I have not had time to discuss specific institutional features of developing countries, nor to discuss empirical evidence for any of the models mentioned.[13] (Although it is worth mentioning that many of the lessons I have suggested have been identified as playing a role in the successful growth performance of the Irish economy over the past forty years.)[14] Among the policy lessons I would highlight are: the importance of a political consensus, to ensure a stable long-run policy environment (resisting both political pressures and academic proposals to tinker with it); generalised rather than firm-specific policies to encourage R&D, with a cautious attitude towards research joint ventures except when they are export-oriented; and an emphasis on raising the general level of research expertise in the economy rather than providing targeted R&D subsidies.

[13] Though I should mention Griliches's (1992) summary of the empirical work on spillovers, which typically finds values of $ between 0.2 and 0.4; and, from among a great deal of circumstantial evidence confirming the importance of absorptive capacity, the findings of Blomström and Sjöholm (1999) and Navaretti and Carraro (1997) that spillovers are higher and RJV's more likely to form between firms with *similar* levels of technological expertise.

[14] Barry (1999) gives a recent assessment.

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