briefing notes

HOW IMPORTANT IS BUSINESS R&D FOR ECONOMIC GROWTH AND SHOULD THE GOVERNMENT SUBSIDISE IT?

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How important is business R&D for economic growth and should the government subsidise it?

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Summary

A large empirical literature has sought to estimate the rate of return to R&D at the firm and industry levels. In general, this literature finds the social rates of return to R&D to be substantially above private rates of return. These rates of return both inform us of how important R&D is for growth and provide one of the main justifications for government subsidies to R&D. Firms' decisions to undertake R&D are based on their private return to R&D. We believe that because this is lower than the social rate of return, there is under-investment in R&D.

In order to achieve the optimal level of R&D investment, government policy should aim to bring private incentives in line with the social rate of return. The first part of this note considers current estimates of the private and social rates of return to R&D. These estimates suggest that the gap between private and social rates of return is quite large.

A comparison of the levels of R&D intensity in the business sector is then made across countries. The UK has the lowest R&D intensity of the G5 countries and, perhaps more worryingly, the trend has been flat while in other countries R&D intensity has been increasing over time. This is reflected in lower productivity levels in the UK (although there is much debate over the measurement of productivity and the size of this gap).

What then can and should the government be doing to increase the amount of R&D done in the UK? There are a large range of policy instruments that could affect the share of

[‡] This note draws on joint work with Nick Bloom, Stephen Redding and John Van Reenen.

GDP that is invested in R&D. Indirect policies such as competition policy and regulation may be important. Direct policies include direct funding of R&D, investment in human capital formation, extending patents protection and tax credits for R&D. R&D tax credits have become a popular policy tool, with many countries offering subsidies of this form. Recent empirical evidence suggests that R&D tax credits are an effective instrument, although there are many remaining questions about their desirability. Do they increase the total amount of R&D or is their main impact to reallocate R&D between countries, i.e. is the increasing use of R&D tax credits one form of tax competition between countries for a mobile activity? In a world with multinational firms, one issue that arises is whether it is R&D in the UK or R&D by UK firms that we are concerned with. Does an increase in R&D expenditure lead to increases in the knowledge stock, or does it simply lead to higher wages for R&D scientists, as has been suggested by recent work in the US? Is it possible to provide subsidies to the extent needed to raise R&D intensity in the UK to the level in other G5 countries, without creating other distortions to economic activity?

It is difficult to design and implement an effective subsidy to R&D without taking a view on the answer to at least some of these questions.

How important is R&D for economic growth?

Economic theory emphasises the accumulation of R&D and human capital in explaining economic growth.[1] We can answer the question in the heading above by looking at how much output will increase when the level of R&D input increases. We measure this by estimating the elasticity of output with respect to capital stock. This is equal to the rate of return to R&D multiplied by the share of the R&D stock in output.

A large empirical literature has sought to estimate the rate of return to R&D. In general, the empirical literature finds the social rates of return to R&D substantially above private rates of return.[2] These findings are summarised by Griliches (1992): ‘In spite of (many)

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[1] See, for example, Aghion and Howitt (1992).
[2] Examples include Griliches (1980), Griliches and Lichtenberg (1984a and 1984b) and Hall and Mairesse (1995).

difficulties, there has been a significant number of reasonably well-done studies, all pointing in the same direction: R&D spillovers are present, their magnitude may be quite large, and social rates of return remain significantly above private rates'.

The private rate of return can be estimated by looking at the impact of a firm's own R&D on the firm's output.[3] Estimates of the private rate of return to R&D are made using US firm-level data in Griliches (1992). The estimated elasticity of output with respect to R&D is around 0.07. This says that for a 10% increase in R&D expenditure there will be a bit less than a 1% increase in output (0.7%). This implies a rate of return of around 27% for R&D.[4] Hall (1996) reports that estimates of private rates of return to R&D cluster around 10–15% though can be as high as 30% in some studies.

The social rate of return is generally obtained by estimating the impact on growth in one firm of R&D done in other firms. These other firms could be within the same industry or the same country or in related industries (for example, an upstream industry that supplies parts) or related countries (for example, a trading partner).

What about estimates of the social rate of return to R&D? One of the main reasons why the social rate of return is believed to be higher is that we think that knowledge spills over from the inventor to other firms. Once invented, an idea can be imitated by others (it is non-rival and only partially excludable), although patent protection and delays in the dissemination of new ideas enable the innovator to appropriate a share of the rents from a new idea. Care must be taken in interpreting estimates of the social rate of return to R&D. Estimates that are carried out at the firm level capture the social return to that firm. Those at the industry level capture the social rate of return to that industry but not spillovers to other industries. Similarly, estimates conducted at the national level capture within-

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[3] The most common way of obtaining estimates of the rate of return to R&D is from the parameters of a production function. Output is produced by combining capital (*K*) and labour (*L*), and *A* defines total factor productivity, $Y_{it} = A_{it} F(K_{it}, L_{it})$. Total factor productivity will be affected by many factors, one of which is the stock of knowledge (*G*). This can be written $\ln A_{it} = \eta \ln G_{it} + \beta \ln X_{it}$ where *X* denotes all other factors. The parameter $\eta = (\partial Y_{it} / \partial G_{it}) \times (G_{it} / Y_{it})$ is the elasticity of output with respect to knowledge stock and $r = \partial Y_{it} / \partial G_{it}$ is the rate of return to the accumulation of knowledge (which we can proxy by R&D expenditure, the flow of investment in knowledge).

[4] The ratio of R&D stock to value added is around 0.26 in his sample; 0.07=r×0.26 implies r=0.269.

country spillovers but not those between countries. In addition, an important part of innovative output is the introduction of new goods, and considerable difficulties arise in measuring the value and benefit of these new goods. Table 1 summarises estimates of the social rates of return in manufacturing industries[5] from a number of empirical studies in the productivity literature.

Table 1: Estimates of the social rate of return to R&D in manufacturing, industry level

Study	(1) Own R&D	(2) Used R&D	(1)+(2)	Years	Obs.
Terleckyj, 1980	0.25 (0.08)	0.82 (0.21)	1.07	1948–66	20
Sveikauskas, 1981	0.17 (0.06)	—	—	1959–69	144
Scherer, 1982	0.29 (0.14)	0.74 (0.39)	1.03	1973–78	87
Griliches and Lichtenberg, 1984a	0.34 (0.08)	—	—	1969–73	27
Griliches and Lichtenberg, 1984b	0.30 (0.09)	0.41 (0.20)	0.71	1969–78	193
Griliches, 1994	0.30 (0.07)	—	—	1978–89	143

Notes: All studies are carried out on manufacturing industries only except Scherer (1982) which includes some service sectors. Numbers in parentheses are standard errors.
Source: Jones and Williams, 1998.

Column 1 in Table 1 shows the social rate of return to industry from R&D conducted by firms within the same industry. These estimates range from 17% to 34%. The second column shows the social return attributable to R&D conducted in one industry but used in another (for example, R&D carried out in an upstream industry). Estimates of the social rate of return on this R&D are significantly higher. Adding the two together implies a social rate of return of around 100%. These estimates are largely based on data for the manufacturing sector.

Empirical results on the social rate of return to R&D are integrated into a macroeconomic model of endogenous innovation and growth by Jones and Williams (1998). They show that the estimates of the social rate of return in the R&D literature (i.e. the studies shown

[5] Scherer (1982) includes some service sectors.

in Table 1) actually provide a lower bound to the true social rate of return, once we take into account the dynamic general equilibrium effects emphasised in the endogenous growth literature.

Another way in which these models will underestimate the social rate of return to R&D is that they assume that imitation is costless. However, knowledge is 'tacit' in nature: it takes time and effort to explain new ideas to others and to codify inventions in manuals and textbooks. This means that imitation itself can be costly.[6] Recent work has emphasised the role that R&D plays, not only in leading to new innovations but also in enhancing firms' ability to imitate. R&D not only stimulates innovation but also plays an important role in the adoption of existing technologies. Empirical evidence lends support to these ideas.

Griffith, Redding and Van Reenen (2000) present an empirical framework in which the rate of return to R&D is composed of an effect on productivity through innovation and an effect through increased potential for imitation. This second component will be particularly important for firms, industries and countries far behind the technological frontier. Innovation and technology transfer provide two potential sources of productivity growth for countries behind the technological frontier. A country's distance from the technological frontier is used as a direct measure of the potential for technology transfer, where the frontier is defined for each industry as the country with the highest level of total factor productivity (TFP). The further a country lies behind the technological frontier, the greater the potential for R&D to increase TFP growth through technology transfer from more advanced countries.[7]

Griffith et al. (2000) provide econometric evidence that R&D expenditure plays a role in assimilating the research discoveries of others as well as its conventional role as a source of innovation. The size of the spillovers depends on one's own R&D activity. Table 2 shows the estimates of the national social rate of return to R&D from both innovation and

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[6] Mansfield, Schwartz and Wagner (1981) present evidence of substantial costs of imitation (on average, 65% of innovation costs), while the average length of time for imitation is found to be 70% of that taken for innovation.

[7] See Cameron (1996) for an analysis along these lines of Japan and the US and see Cameron, Proudman and Redding (1998) for an analysis of the UK and the US.

imitation. Column 1 of the table reports the exponent of average relative TFP_{t-1} in total manufacturing during 1974–90 in each country in the sample. This number is 1 for the frontier and less than 1 for all non-frontier countries. The US is frontier most often so its relative TFP is near 1.

Table 2: Estimates of the social rate of return to R&D in manufacturing, national level

	(1) Mean relative TFP Frontier=1.000	(2) National return to R&D, including both innovation and imitation
Canada	0.826	57.2%
Denmark	0.728	67.9%
Finland	0.525	95.2%
France	0.849	54.9%
Germany	0.901	49.9%
Italy	0.696	71.6%
Japan	0.703	70.8%
Netherlands	0.905	49.6%
Norway	0.663	75.6%
Sweden	0.726	68.0%
UK	0.626	80.5%
US	0.994	41.7%

Note: Mean relative TFP is the average value of lagged relative TFP in total manufacturing during 1974–1990.
Source: Griffith, Redding and Van Reenen, 2000.

Column 2 of Table 2 uses the value of average relative TFP to calculate the implied total rate of return to R&D (from both innovation and absorptive capacity). In the estimated model, the rate of return from innovation is assumed to be constant across countries and is estimated to be 41.2%. The social rate of return to R&D in the US is indeed due almost entirely to innovation (a total rate of return of 41.7% compared to a rate of return from innovation of 41.2%). In contrast, average relative TFP in Finland is just over 50% of the frontier's, and less than half of R&D's social rate of return (95.2%) is due to innovation – absorptive capacity is more important than innovation.

One important conclusion from the analysis is therefore that many existing studies, in so far as they are based on US data (a country which is typically the frontier), will tend to underestimate the full (world) social rate of return to R&D. In non-frontier countries, there is the potential for R&D to generate TFP growth from both innovation and technology transfer.

This conclusion receives independent support from Eaton, Gutierrez and Kortum (1998), who calibrate a computable general equilibrium model of endogenous innovation and growth to economy-wide data from 21 OECD countries. With the exception of Portugal, research productivity in all other OECD countries is found to be higher than in the US. This of course raises the question of why many non-frontier countries do not undertake more R&D. One answer may be the difference between private and social rates of return – if some of the technology transfer induced by R&D activity takes the form of an externality, it will not be internalised by private sector agents. Unfortunately, we do not have good internationally comparable estimates of the private rate of return to R&D. Eaton et al. (1998) calculate an estimate of the value of invention relative to the reward for production work (an average wage) and find that incentives to carry out R&D are much lower than those in the US and Japan in all countries. In the UK, for example, the incentive to do research is 0.372, compared with 1.0 in the US and 0.504 in Japan. The explanation provided by Eaton et al. is that research incentives are lower due to smaller market size in other OECD countries. Market failures such as underdevelopment of financial markets may also act as barriers to R&D investment.

How much R&D do we do in the UK?

Historically, the share of GDP devoted to R&D in the UK has been comparable to that in the other G5 countries. In 1974, the UK was amongst the highest, with 1.4% of GDP devoted to business enterprise R&D (BERD) – see Table 3. However, over the 1980s, the R&D intensity levels in the other G5 countries increased faster than in the UK, and the UK now has a smaller proportion of GDP devoted to R&D and significantly less than in any other G5 country.

Note, however, that UK firms also conduct considerable amounts of R&D abroad. For example, in 1996 the expenditure of US affiliates of UK firms on R&D was $2,525 million and they employed 16,400 R&D workers.[8] UK-owned firms are amongst the largest foreign research centres operating in the US. This raises the tricky question of whether it is R&D conducted in the UK (by UK and foreign firms) or whether it is R&D conducted by UK firms (wherever in the world they choose to conduct it) that we care about. This depends on a number of issues – what type of R&D firms are doing overseas (is it targeted at local markets or exportable to their home market?) and how important geographic proximity is for spillovers.

Table 3: Industrial R&D as a proportion of GDP

	1974	1981	1991	1996
France	1.04	1.12	1.48	1.69
Germany	1.29	1.71	1.87	1.87
Japan	1.18	1.41	2.16	2.30
UK*	1.36	1.49	1.28	1.10
US	1.57	1.71	2.07	2.42

** UK figures exclude UK Atomic Energy Authority in all years (official figures include them after 1986).*
Source: OECD BERD, various years.

Should the government promote R&D?

First of all, it is worth noting that government policy already does promote R&D in many ways. Around 32% of gross national expenditure on R&D in 1996 was funded by government (37.2% of this on defence).[9] The government also promotes innovative activity in firms through direct spending on education and training, patent protection, regulation and competition policy.

The finding that social rates of return to R&D are substantially above private rates of return provides one of the main justifications for government subsidies to R&D. Firms' decisions to undertake R&D are based on their private return to R&D. We believe that because this is lower than the social rate of return, there is under-investment in R&D. The estimates discussed above suggest that the gap between private and social rates of return is quite large.

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[8] Serapio and Dalton, 1999.
[9] *Science, Engineering and Technology Statistics, 1998*. See Stoneman (1999) for discussion of government spending on R&D.

The optimal subsidy to R&D would equate private and social rates of return. If we take the estimates of the private and social rates of return to R&D from the literature at face value, they suggest substantial under-investment in R&D. For example, assume that there are a large number of potential R&D projects to be undertaken and that the return on these declines at a uniform rate. If we take a conservative estimate of the social rate of return to R&D of 30% and a private rate of return of 7–14%, this implies that we should optimally be spending on R&D a share of GDP *two* to *four* times larger than we are currently.

Achieving this scale of increase in R&D expenditures would involve very large subsidies. A major consideration would have to be whether such subsidies could be designed to target R&D expenditure without introducing significant distortions to other aspects of economic activity.

How can the government promote R&D?

The types of policy that affect firms' incentives to invest in R&D are numerous and diverse. Policies that directly target R&D include direct funding of government R&D labs, universities or business, investing in human capital formation, patent protection laws and R&D tax credits. Other policies, not directly targeted at R&D, which may have a significant impact on the level of R&D investment include competition policy and regulation (particularly within high-R&D industries such as pharmaceuticals and telecommunications).

Incentives for firms to invest in R&D and innovation are generally thought to be affected by competitive conditions. Theoretical work gives us ambiguous predictions about the direction of this effect – there are reasons why a competitive environment provides greater incentives to invest in R&D, and reasons why a less competitive environment should lead to higher R&D activity.[10] The empirical literature tends to favour the idea that more competition leads to more innovative activity in the aggregate.[11] Patent protection grants firms monopoly power for a period of time and thus allows them to

[10] See, *inter alia*, Reinganum (1983) and Cohen and Levin (1989) for surveys of this literature.

recoup some of the difference between the private and social rates of return, although this comes with costs associated with monopoly pricing. R&D tax credits are increasingly being adopted and are considered here in more detail.

Are R&D tax credits effective?

In an effort to increase their level of innovation, many countries have turned to fiscal incentives for R&D, often involving substantial sums of taxpayers' money. The US General Accounting Office (1989) estimated that R&D tax credits cost approximately $7 billion in revenue during the 1981–85 period. More recent estimates suggest that the US R&D tax credit will cost around $2.24 billion in lost revenue over fiscal years 1997 through 2002 (Gravelle, 1999). The European Commission's (1995) survey on state aid suggests that its members spent over $1 billion per annum on R&D tax incentives during the early 1990s.

Tax incentives seem a natural policy tool for a market-oriented government wanting to increase R&D expenditures. Firms decide where and how to spend their R&D budgets rather than this being determined through a bureaucratic central authority.

Economists, however, have traditionally been sceptical over the efficacy of fiscal provisions, partially for the reason that the absolute tax price elasticity of R&D was believed to be low. In addition, there are many problems with design and implementation of tax credits.[12] Bloom, Griffith and Van Reenen (1999) use variation in the user cost across countries to estimate the impact of changes in the price on the level of R&D investment. There is considerable variation in the user cost of R&D within and across countries induced by the very different tax systems that have operated over the sample period. The econometric analysis suggests that tax changes significantly affect the level of R&D even after controlling for demand, country-specific fixed effects and world macroeconomic shocks. The impact elasticity is not large (of the order of –0.1), but over the long run it may be more substantial (about –1). These figures suggest that a 10%

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[11] See, *inter alia*, Geroski (1995) and Blundell, Griffith and Van Reenen (1999).
[12] See Griffith, Sandler and Van Reenen (1995) for a discussion of these in the UK context.

reduction in the price of R&D would lead to a 1% increase in the amount of R&D in the short run and a 10% increase in the long run.

A large number of other studies estimate the reaction of firms to changes in the user cost of R&D. Estimates of the own-price elasticity range from –0.3 to –2.0, although, in a review of the literature, Hall and Van Reenen (1999) conclude that the most believable estimates are around –1.0. This suggests that a 1% change in the user cost of R&D will lead to a 1% change in R&D expenditure.

Are R&D tax credits desirable?

Should one conclude, then, that R&D tax credits are desirable? Showing that they are effective does not imply that they are desirable. Several other elements would have to enter a cost–benefit analysis in addition to the elasticity of R&D. These include administrative costs accruing to both firms and the government, problems with designing an effective tax credit (many potentially perverse incentives have been induced by the design of different credit systems) and concerns with tax competition.

We may have concerns about whether observed increases in R&D expenditure represent genuine increases in knowledge output, or whether firms are relabelling other activities as R&D. A related issue is raised by Goolsbee (1998) of whether the impact of R&D subsidies is mainly to increase salaries of scientists and engineers. The largest part of R&D spending (up to 50%) is on salaries of scientists. It is likely that the labour supply of these scientists is quite inelastic, so that when the government provides a subsidy to R&D, this is spent on increased wages rather than on new R&D. Goolsbee provides evidence that this has been the case in the US. There may still be positive benefits of these subsidies from encouraging people to become scientists or from increasing their effort at work by paying them higher salaries; however, if these are the objectives of the policy, there may be better ways of designing the subsidy.

Evidence presented in Bloom, Griffith and Van Reenen (1999) suggests that the location of R&D may be affected by tax-induced changes in the cost of R&D, which indicates that fears about tax rivalry in R&D policy are not completely without empirical foundation. This raises the issue of whether subsidies to R&D are leading to an overall increase in the level of R&D, or whether the primary effect has been to reallocate R&D between countries.

Unfortunately, many unanswered questions remain about the extent to which and how we can subsidise R&D. This means that the government should tread carefully in trying to design and implement any particular policy. While there is a strong rationale for subsidising R&D, there are many potential pitfalls and we could end up causing more problems than we solve.

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