Fiscal Studies (1996) vol. 16, no. 2, pp. 21-44

Tax Incentives for R&D

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I. INTRODUCTION

A long-standing concern surrounding the performance of the UK economy is its perceived failure to maintain the same technological pace as its competitors. Industrial research and development (R&D) expenditure[2] as a proportion of GDP fell during the 1980s at a time when all other G7 countries increased the proportion of their output given over to R&D. This ratio is now lower in the UK than in most other G7 countries. If this world-wide trend toward more R&D indicates that industrial production is becoming increasingly science-based, then the UK may be in danger of becoming a relatively low-tech economy. One purpose of this article is to examine whether there is a rational basis for these fears.

The explicit policy of the UK government has been to move away from the direct funding of R&D. The recent White Paper on Science and Technology[3] emphasised diffusion and technology transfer as the key policy initiative.

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The authors would like to thank Richard Blundell, Michael Devereux, Naercio Menezes Filho, Annette Ryan and participants in the OECD conference on fiscal incentives for R&D and the 1994 Industrial Economists Study Group meeting at the London Business School. This work is part of a programme of research at the ESRC Centre for the Microeconomic Analysis of Fiscal Policy at the Institute for Fiscal Studies.

[2] This refers to business expenditure on research and development (BERD) performed in the UK (by UK firms and others). It includes government-funded R&D performed by the corporate sector, but not publicly performed R&D (in universities or by the Ministry of Defence, for example).

[3] 'The Government does not consider there to be a case for general tax incentives for spending on R&D' (HMSO, 1993, p. 13).

Reacting to this, the Commons Science and Technology Committee[4] has called for a review of the case for fiscal incentives to increase the level of business expenditure on R&D. It points to recent studies in the US indicating that the gains in new R&D have been at least equal to, if not greater than, the revenue cost of the incremental tax credit. However, one cannot simply say that what has been successful in the US will necessarily be successful elsewhere. The UK, like most other European nations, has a relatively small and open economy and many of the firms that would benefit from a tax incentive do much of their R&D overseas.

In considering the introduction of new fiscal incentives for R&D, it is important to be clear about which activities such incentives are meant to encourage and whether the tax system is the most appropriate policy tool. There are also substantial design and implementation difficulties that need to be considered. Empirical studies of the impact of the US tax credit emphasise its distortionary nature, with many companies facing a negative effective credit giving them a disincentive to invest in R&D.[5] This surprising asymmetric impact on firms arises because of the structure of the credit and is detailed below (see Section VI). The design problems cannot be dismissed merely as administrative details.

The focus of this article is on the role of R&D-related tax incentives. There are many aspects of the tax system that may indirectly affect the cost of R&D which are not considered, such as subsidies for complementary assets to R&D (for example, training). Tax incentives are only one way in which the government can affect the amount of R&D undertaken and its economic impact. Technology policies that encourage the diffusion of innovation, increase the level of private reward through patenting arrangements and provide easier access to finance through low- interest or government secured loans may all affect the level, location and type of R&D that is carried out.

A host of incentives exist that are targeted at specific regions (areas of high unemployment, for example) or industries. These types of incentives are based on more direct government intervention and are not the subject of this article. The emphasis here is on general tax incentives that provide a subsidy to R&D spending relative to other forms of investment. In examining the impact of a tax incentive on the amount of R&D conducted, it is necessary to know how it affects the price of R&D and how firms respond to this change in price. Given knowledge of these effects, it is possible to estimate whether the revenue forgone is less than or equal to the amount of private sector R&D generated. Ideally, a further calculation would measure the extra spillover benefits created by the additional R&D. Unfortunately, in the absence of sufficient information

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[4] HMSO, 1994.

[5] For example, one appraisal of the US tax credit found that 30 per cent of sampled firms in 1989 faced these negative marginal effective credits (Hall, 1993, Table 3).

regarding such macroeconomic effects, most research has fallen back on the simpler yardstick of examining whether £1 of tax credit generates at least £1 of additional R&D.

Section II outlines the reasons why society might want to subsidise R&D and discusses their implications for policy design. Section III briefly outlines the patterns of R&D spending. Section IV sets out the current tax treatment of R&D in several OECD countries, and Section V details the impact of tax on the cost of doing R&D. Issues arising about the design and implementation of fiscal incentives are discussed in Section VI, and Section VII looks at the impact of differences in the price of R&D. Conclusions are drawn in Section VIII.

II. WHY SUBSIDISE R&D?

Technological progress has long been seen as the engine of economic growth. Schumpeter (1942) popularised the idea that capitalism's great strength lay in dynamic efficiency — innovation leads to greater productivity and the possibility of a larger quantity and variety of goods at lower cost. This view contrasts with the traditional economic concept of static efficiency which concerns the optimal allocation of resources in any one time period. Econometric work tracking the factors responsible for productivity growth generally find a large role for technical progress.[6]

R&D spending has risen across the industrialised world and, in particular, industrial R&D performed and largely financed by business enterprises has shown a remarkable increase. In 1985, $155.2 billion was spent on industrial R&D in the OECD countries, and there was an average annual real growth rate of 6 per cent between 1975 and 1985 (OECD, 1989). This increase was faster than average GDP growth and most countries have seen a rise in the ratio of R&D to GDP or physical capital. Most commentators attribute this trend to a global movement towards more science-based production in the industrialised nations, especially in manufacturing.

However, the overall rise disguises a large variation in performance between countries. Table 1 shows that the growth of R&D intensity has been much greater in some countries — Japan, for example — than in others, such as the UK. In fact, the UK is the only country to show a decline during the 1981–91 period amongst the G7 countries (these countries accounted for 91 per cent of total OECD R&D in 1985).

This decline has led many to call for greater tax breaks for R&D. Underlying this demand is the assumption that the market is failing to provide the correct incentives for firms to invest in R&D, and that government can successfully

[6] Classically, Solow (1957) found that over two-thirds of US productivity growth before the First World War could not be accounted for by the standard factor inputs of capital and labour. More recent studies with better adjustments for quality have reduced the size of this residual, but it remains substantial (e.g. Maddison, 1987).

intervene. There are several possible reasons why the market may be failing to provide enough R&D investment and the policy implications of each are quite different. Tax policies may provide a viable means of overcoming certain market failings, but may make matters worse for other sorts of market failure. The main economic argument in favour of government support for industrial R&D, which is based on the idea that society benefits from this R&D via ‘spillovers’, is considered first, and then rationales due to further market failures are discussed.

TABLE 1

Industrial R&D as a Proportion of GDP

	1974	*1981*	*1991*
Canada	0.41	0.60	0.81
France	1.04	1.12	1.48
Germany	1.29	1.71	1.87
Japan	1.18	1.41	2.16
UK[a]	1.36	1.49	1.28
US	1.57	1.71	2.07

[a] UK figures exclude UK Atomic Energy Authority in all years (official figures include them after 1986).
Source: OECD, 1994.

Technological spillovers occur when the research activities of one firm induce higher productivity in other firms. To the extent that knowledge cannot be fully appropriated, there will generally be an underinvestment in R&D. Even with patent protection, imitators can often copy without having to fully compensate the original innovator for the costs of research and first commercialisation of new ideas. There is a substantial body of both econometric and case-study evidence supporting the existence of spillovers.[7] Whatever the precise nature of the way spillovers are diffused, in a closed economy the classic solution to the spillover problem is for government to subsidise R&D to bring the marginal private rate of return up to the marginal social rate of return.

It may be, however, that even in this simple case, a tax subsidy is not the appropriate tool. The patents system was designed to increase the appropriability companies have over their own research. Nevertheless, it is clear that patents are a relatively poor way of ensuring appropriability outside of a few particular industries, such as pharmaceuticals.[8] In recent years, R&D Joint Ventures (RJVs) have been touted as a private sector response to the spillover problem. Under an RJV, companies agree to partially pool their informational resources and, if all the potential beneficiaries from spillovers are in the RJV, the public

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[7] While there are reasons for a strategic incentive to overinvest in R&D, the empirical evidence is largely in favour of the underinvestment hypothesis. See Griliches (1992) for a survey.
[8] See Levin, Klevorick, Nelson and Winter (1987).

good may effectively turn into a private one.[9] The major problem with encouraging joint ventures, of course, is the opportunity it gives for firms to enhance their market power through collusive activities.

In an integrated and open economy, where multinationals conduct R&D and business abroad and foreign firms conduct R&D and business domestically, it is questionable exactly which activities a government would want to subsidise. The general presumption is that domestically performed R&D is important, as spillovers are geographically clustered around where the research takes place. Although there is some evidence supporting this proposition,[10] there are also substantial international spillovers in productivity.[11] Additionally, R&D may be performed in one country but the innovations produced in another. The beneficial employment effects of R&D for skilled workers, for example, are more likely to come from the production of high-technology goods rather than R&D *per se*. This opens up the opportunity for some countries to 'free ride' on the R&D efforts of other countries. This result may be entirely rational for an individual country, but will be inefficient from a global perspective.

Another reason for placing little weight on where firms do their R&D is the fact that these firms will, presumably, conduct their R&D in the location that maximises profits. Since R&D is considered more productive there than elsewhere, why interfere with market choice? The problem with using tax incentives to benefit local multinationals is that it is unclear what a 'French', 'Dutch' or 'British' multinational really is. The shareholders of multinational corporations are dispersed over many countries. To the extent that policymakers are concerned about the welfare of only their own citizens (i.e. as shareholders in multinational corporations), enhancing the profitability of multinationals that happen to have their headquarters based in their country may only have very indirect social value.

Those who stress the locational importance of R&D do not only rely on arguments based on the geographical clustering of R&D spillovers to productivity. More domestic R&D could also generate more employment and higher wages. These benefits are likely to affect skilled workers disproportionately, as numerous studies have shown that new technology tends to increase the demand for human capital.[12] Skilled workers are generally in short supply, and it is doubtful whether increasing their demand through increased R&D is desirable without first addressing the apparent failures in the training and education systems.

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[9] See Katsoulacos and Ulph (1995) for a recent analysis.
[10] See, for example, Audretsch and Feldman (1994).
[11] See Coe and Helpman (1993) or Bernstein and Mohnen (1994). Both these analyses are purely at the macroeconomic level, however. Coe and Helpman also assume a priori that spillovers are transmitted by importing high-tech goods from other countries.
[12] See Berman, Bound and Griliches (1994) for a recent example.

A further argument in favour of increasing R&D expenditure is that a wider base of firms conducting R&D domestically could enhance an economy's ability to imitate R&D conducted in other countries. There is certainly evidence at the microeconomic level indicating that firms need to be doing some R&D in order to capture R&D spillovers.[13] One needs a scientist who can at least understand the latest advances in his or her field in order to begin developing new products based upon those advances.

All of these arguments raise the question of what parts of a company one wants to attract to the UK — the headquarters, the R&D laboratory or the manufacturing plant? Is there anything that is intrinsically special about R&D? Like other forms of investment incentives, R&D tax credits raise issues of tax rivalry. Nations may bid against each other to attract R&D laboratories, with the associated drain on the taxpayer.

The strongest case for a tax-privileged treatment of R&D is based on some version of the spillover argument. Yet there are other market failures that might lead to an underinvestment in R&D. The lack of skilled workers has already been noted. In addition, R&D relies heavily on internal funding and there are many reasons why markets may not be working to provide adequate financing.[14] Tax measures that increase a firm's cash flow may therefore increase R&D investment. One of the problems with providing a subsidy to R&D through the tax system is that it may not benefit the businesses that need it most — for example, small, growing firms that are liquidity-constrained but do not have tax liability against which to offset a tax credit. Fundamentally, if one believes that financial markets are at the heart of the problem, then acting on *this* market failure is the more appropriate policy response. Similarly, if it is the skills shortage that is holding back R&D investment, then it is training policy, not R&D policy, that should be tackled. Those calling for R&D tax credits must be clear that this solution adequately tackles the actual cause of the shortfall in R&D spending, and that a tax credit is the appropriate fiscal response. Otherwise, R&D tax credits are acting on a symptom rather than the disease.

III. PATTERNS OF R&D INVESTMENT

As emphasised in the introduction, not only has real R&D grown over time along with other forms of investment, but it has also grown faster. The proportion of GDP given over to R&D has increased across the industrialised world, primarily

[13] See Cohen and Levinthal (1989).

[14] For example, R&D cannot be secured by banks as a tangible asset. Furthermore, there are problems with asymmetric information between potential lenders and R&D-performing firms. These are deep-seated difficulties because firms may be reluctant to reveal sensitive information as it may leak out to competitors during the lending negotiations. For evidence on the importance of liquidity constraints for investment in general, see Bond and Meghir (1994); for the R&D case in particular, see, *inter alia*, Hall (1990) and Himmelberg and Peterson (1994).

because production has become more science-based. Differences in the average level of R&D intensity across countries are less easily explained. In part, these are due to the different configurations of industries across countries. Britain stands out as having a relatively high level of R&D intensity in 1974 (second only to the US), but by 1991 has one of the lowest of all the G7 countries (bar Canada).

It could be argued that Britain was spending too much on R&D in the early 1970s and the decline is welcome.[15] Yet even those who argue that this pattern is of no concern to policymakers should be interested in why Britain has experienced a relative decline in its R&D intensity.[16] One explanation stresses de- industrialisation. It is true that manufacturing declined faster in Britain than elsewhere and that the bulk of R&D is concentrated in manufacturing. Nevertheless, when one examines the ratio of R&D to GDP within manufacturing, Britain's performance remains poor. R&D intensity fell from 6.3 per cent in 1981 to 6.1 per cent in 1992[17] whereas it rose in all the other G7 countries. A second explanation could be that the 'Peace Dividend' is responsible.[18] However, the stagnation of British R&D intensity began in 1981, long before the end of the Cold War, and other countries with a large amount of military R&D, such as France and the US, have not suffered so badly. One underexplored possibility is that there are relatively greater shortages of skilled workers in Britain, making R&D and innovation more expensive.

The composition as well as the quantity of R&D has evolved. As multinationals have grown and the world's markets have opened, R&D has become more international in two senses.[19] First, more R&D is directed at expanding sales in foreign markets. Secondly, R&D conducted domestically is increasingly financed from overseas. In Britain, for example, the proportion of total R&D financed from overseas rose from 6.9 per cent in 1983 to 11.7 per cent in 1993. As a further example of the increased importance of foreign markets, one can observe a rise in the ratio of foreign to domestic patents in almost all countries. For example, in the US only 8 per cent of patents granted were to foreigners in 1968, 38 per cent in 1978 and 46 per cent in 1992.[20] This trend towards internationalisation is more pronounced for British and Canadian corporations which performed a relatively larger proportion of their technological activities overseas. According to Cantwell (1992) and Patel and

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[15] See, for example, Edgerton (1993).
[16] The following draws on Ryan and Van Reenen (1995).
[17] These figures relate to manufacturing R&D to value added in OECD (1994).
[18] British R&D has a greater military bias than other countries'. In the 1950s, about half of all British R&D was defence-related (Edgerton, 1993). Even in 1985, about 21 per cent of total R&D was defence-based whereas the EU average stood at 11.2 per cent.
[19] See Granstrand, Håkanson and Sjölander (1993) for a recent survey.
[20] These figures reflect both an increase in the amount of R&D performed by foreign-based firms in the US and an increased desire of foreign firms to market their goods in the US.

Pavitt (1992), around 30 to 42 per cent of UK R&D was performed abroad, while Hines (1993a) gives the US figure as closer to 10 per cent.

Another feature of R&D is that it is labour-intensive. R&D expenditure is primarily current expenditure, the majority of which is comprised of salaries and wages of scientists and engineers. As a consequence, much R&D knowledge is embodied within individuals, and one important form of technological diffusion is the movement of these individuals.

Finally, it must be borne in mind that formal R&D is heavily concentrated in certain industrial sectors, and predominantly performed by the larger firms within these sectors. Chemicals and engineering are generally the largest R&D performers, with pharmaceuticals being a particularly high and successful R&D spender in the UK. For example, in 1989 the 50 largest R&D spenders accounted for 76.5 per cent of all British R&D expenditure and 73 per cent of all R&D employment.[21] An implication of this concentration of R&D (which is higher than the concentration of production) is that R&D subsidies will be enjoyed disproportionately by a small number of firms.

IV. TAX TREATMENT OF R&D

In this section, the tax treatment of expenditure on R&D in six OECD countries is discussed, and in the next section, its impact on the price of conducting R&D is presented. Investment in R&D is treated more favourably than investment in physical capital in most countries through accelerated depreciation allowances and tax credits. The tables below present only a very simplified description of the tax systems. The rates shown are the ones used in calculating the cost-of-capital figures. The Appendix gives a more detailed description of the tax systems.

The first column in Table 2 shows the statutory corporate income tax rate. The next four columns show the rate at which plant and machinery and buildings are allowed to be depreciated for calculating tax liability. In many countries, there is a variety of rates and methods of calculating depreciation allowances. The ones shown in the table are the ones used in the calculations below and are generally an average of the actual rates.

Four of the countries give a tax credit on R&D expenditure as shown in Table 3. These sometimes apply to incremental spending above a base, the idea being to provide a subsidy to marginal investment but not to inframarginal R&D. In addition, the definition of R&D expenditure varies significantly from country to country.

The tax treatment of R&D in two other countries is worth mentioning, although we do not discuss them in detail here. Australia gives a tax credit of 50 per cent on all R&D spending, which is more generous than any of the measures

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[21] *Business Monitor* MO14.

mentioned above. The Netherlands has introduced the idea of allowing the tax credit to be deducted from the firm's payroll tax, which effectively avoids any danger of tax exhaustion.[22]

TABLE 2

Corporation Tax

Per cent

		Depreciation allowances			
	Statutory tax rate[a]	*Plant and machinery*	*R&D plant and machinery*	*Buildings*	*R&D buildings*
Canada[b]	22.8	25.0	100.0	4.0	4.0
France	33.3	35.7	50.0	5.0	5.0
Germany[c]	48.4	30.0	30.0	10.0	10.0
Japan[d]	50.0	30.0	30.0	6.6	6.6
UK[e]	33.0	25.0	25.0	4.0	4.0
US[f]	35.0	28.6	28.6	3.2	3.2

Note: Plant and machinery is depreciated by the straight-line method in all countries except Canada, where it is by declining balance, and buildings is depreciated by declining balance in all countries.
[a] This is the statutory tax rate for retained earnings.
[b] This is the federal tax rate less provincial abatement, plus federal surtax of 3 per cent and less manufacturing or processing profits deduction. Additional provincial tax at an average of 11.9 per cent is also included in the calculations below.
[c] Additional trade tax (*Gewerbesteauer*) of 13 per cent is also included in the calculations below.
[d] This is made up of national, enterprise and inhabitants corporation tax.
[e] This does not include the allowances for 'scinetific research'.
[f] Additional state taxes at an average of 6.5 per cent are also included in the calculations below.

Other Tax Incentives

Preferential tax rates are a way of encouraging successful investment and innovation as opposed to just any investment, but are not commonly used.[23] A separate and lower statutory tax rate applies to any profits earned from innovative investment or activity. The obvious problem is in defining which income comes from the specified activity, and therefore this incentive may work best on smaller firms which only engage in a limited number of activities. It may also be the case that even R&D that does not lead to successful innovation is useful.

Another form of incentive which has not been put into practice but which is advocated by Stoneman (1987) is a levy–grant system. The system could be organised at the industry level and could involve all members of the industry

[22] Tax exhaustion occurs when a company is entitled to an offset but cannot use it because it does not have sufficient tax liability.
[23] Belgium is one of the few countries that do use them.

paying a levy which was redistributed proportionally to R&D. This sort of a scheme has several attractions, although many (largely administrative) drawbacks.

TABLE 3

Tax Credit for R&D

	Credit rate	*Definition of qualifying R&D*
Canada	20%	R&D expenditure within Canada, as well as payments to others for conducting R&D.
France	50%	Incremental R&D expenditure within France over the average of the preceding two years, adjusted for inflation.
Germany	—	—
Japan	20%	Incremental R&D expenditure over the largest amount spent in any year since 1996 up to a maximum of per cent of total corporation tax liability.
UK	—	—
US	20%	Incremental R&D expenditure within the US over the company's 'fixed-base-percentage' times its average annual gross receipts over the preceding four taxation years.

V. IMPACT OF TAX TREATMENT

In this section, the tax treatment of investment in R&D is compared with that of capital investment. This comparison can be made in several ways. Expenditure on a 'typical' R&D investment can be compared with that on a 'typical' capital investment where the compositions of the two investments are different. Differences in the cost of capital arise mainly because current expenditure on R&D is treated as an investment from an economic point of view, while other current expenditure is not. A large part of current expenditure on R&D relates to the salaries of scientists and technicians, the full value of which will accrue over several years. An alternative comparison can be made between a specific investment (for example, a given piece of machinery) purchased for use in the R&D laboratory or for production. Both of these comparisons are presented below.

The numbers presented in Tables 4 and 5 are the rate of return required *before* tax to earn a return of 5 per cent *after* tax.[24] This calculation is a function of the tax rates and the tax base and is also affected by the type of finance used, the inflation rate and other economic variables. In this analysis, we have

[24] Referred to as the fixed-*r* approach (see, *inter alia*, OECD (1991)).

assumed that all investment is financed by retained earnings[25] and that inflation is 5 per cent in all countries.

The first column in Table 4 shows the required rate of return for a typical investment in physical capital. The investment is assumed to be entirely domestic and undertaken by a large firm with tax liability. In this analysis, no account is taken of small companies, regional allowances or any other special provisions.[26] In the remaining columns, an investment in R&D is considered, made up of 90 per cent current expenditure and 10 per cent capital expenditure.[27]

The second column shows the required rate of return for a 'typical' R&D investment, as if it were treated like capital investment for tax purposes. The differences between the first two columns arise because of the different composition of the two investments. Since current expenditure is fully deductible, the figures in the second column are all about 5 per cent, the required post-tax rate of return.

TABLE 4

Pre-Tax Rate of Return for 'Typical'

	Capital investment	R&D investment (no special treatment)	R&D investment (with special treatment)		
			Depreciation: 30% Growth 20%	*Depreciation: 30% Growth: 10%*	*Depreciation: 15% Growth: 10%*
Canada	7.2	5.2	-4.9	-4.9	-0.7
France	6.6	5.2	1.1	2.9	3.8
Germany	8.9	5.4	5.4	5.4	5.4
Japan	8.8	5.4	3.2	4.1	4.6
UK	7.1	5.2	5.2	5.2	5.2
US	7.6	5.3	3.5	4.3	4.7

Note: The following assumptions have been made: the 'typical' investment in capital is 36 per cent in buildings and 64 per cent in plant and machinery; the 'typical' investment in R&D is 90 per cent in current expenditure, 4 per cent in buildings and 6 per cent in plant and machinery; economic depreciation rates are 3.6 per cent buildings, 12.25 per cent for plant and machinery and 15-30 per cent for current R&D (the real economic depreciation rate of R&D is estimated to be around 15-30 per cent ; see, for example, Griliches and Mairesse (1984) and Pakes and Schankerman (1984); inflation is 5 per cent for all countries; investment is financed by retained earnings; R&D growth is 10-20 per cent per annum.

[25] In the OECD countries, capital investment is 55 per cent financed by retained earnings and it is generally thought that the figure is even higher for R&D investment.

[26] These factors would substantially alter the cost-of-capital figures but are too numerous to include in an article of this length.

[27] It is worth pointing out that the cost-of-capital calculations are quite sensitive to the weights used. These calculations are based on weights for 1991 from the Central Statistical Office reported in Cameron (1994).

TABLE 5

Pre-Tax Rate of Return for Given Capital Investment

	Building		Plant and machinery	
	Capital investment	*R&D investment*	*Capital investment*	*R&D investment*
Canada	8.2	7.2	6.6	-0.3
France	7.3	6.2	6.2	3.9
Germany	9.7	9.7	8.4	8.4
Japan	9.8	8.7	8.2	7.0
UK	7.6	7.6	6.9	6.9
US	8.7	8.3	6.9	6.0

Note: The following assumptions have been made: economics depreciation rates are 3.6 per cent for buildings, 12.5 per cent for plant machinery and 30 per cent for current R&D; inflation is 5 per cent for all countries; investment is financed by retained earnings; weights and depreciation rates are from OECD (1991).

In the last three columns, the accelerated depreciation allowances and tax credits detailed in Tables 2 and 3 are included using different assumptions about the depreciation rate and annual growth rate of R&D. For countries with a tax credit, there is a large impact, though the size of the impact is sensitive to the assumptions made. Canada has by far the most generous credit because it applies to all R&D spending, not just the incremental amount. The US and Japanese incremental credits are rather less generous than the French one simply because of the rate. For firms without a tax liability, the French credit would be relatively more generous as it is fully refundable after four years.

Canada and France also give accelerated depreciation allowances for R&D capital expenditure, although they have less impact because only a small proportion of the R&D investment is in capital goods. The value of these additional allowances is the amount of the allowance times the statutory tax rate, which means that they are worth more when the tax rate is high. Tax credits, on the other hand, are offset against a company's tax liability and therefore their value is not dependent on the tax rate.

In Table 5, the pre-tax rate of return required to earn 5 per cent after tax on a given capital investment is shown when it is for R&D purposes and when it is not. The first two columns consider an investment in an industrial building and the second two an investment in plant and machinery. Canada offers the most generous tax treatment of R&D investment, with France, Japan and the US giving some tax advantage.

Comparing the required rate of return figures in Table 5 with the R&D intensity data in Table 1, it appears that the tax treatment of R&D has little correlation with the amount of R&D done. Canada, for example, has the most generous tax treatment of R&D and yet has the lowest R&D intensity. This observation has led many to conclude that tax incentives have little impact on the amount of R&D performed. This conclusion may be unwarranted. First, there are numerous other factors affecting the amount of R&D that will vary from country to country. It could be that in the absence of these incentives, the amount of R&D done would be even lower. Secondly, the required rate of return will differ between firms and it is necessary to look at disaggregated data to determine the manner in which tax incentives affect firms' behaviour. The relationship between tax incentives and R&D can only be fully understood by examining the response of individual firms to independent changes in the price of R&D. Research results in this area are discussed below.

VI. IMPLEMENTATION

This section outlines some of the practical problems that have arisen with the implementation of tax credits. The US Economic Recovery Tax Act of 1981, which introduced a tax credit for R&D, and its subsequent revisions are used as an example.[28] The problems can be generalised to other schemes. Five problems that arise in the implementation of these tax measures are considered. They relate to design, permanency, relabelling, the definition of the base and the interaction of the credit with other parts of the tax system.

The most obvious problem with design is that the social rate of return is generally unknown. It almost certainly varies across industries and over time, yet designing a credit to reflect these differences is all but impossible, given our current state of knowledge. The actual rate of the credit chosen in different countries is inevitably the result of a complex political bargaining process even when there is a cross-party consensus on the need for a tax credit.[29]

In the US case, the form of the tax credit was altered substantially in its scope and generosity from year to year, and it still has not been made a permanent feature of the US tax system. The uncertainty over the level and future existence of the credit meant that firms were slow to react because of the large adjustment costs of R&D. Economists[30] argue that these costs stem from the fact that it is very difficult to hire and fire the highly-skilled R&D personnel who make up the bulk of R&D expenditures. R&D investment projects are usually long-term and spending shows little variation year to year compared with capital investment. Large changes to R&D budgets are costly and corporations are unlikely to incur the costs unless they can be sure that the lower R&D prices induced by the credit are not going to be reversed 12 months later. The uncertainty created by the constant change in the US case surely undermined the effectiveness of the credit, especially in its early years.

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[28] See Hall (1993) or Hines (1993a and 1993b) for details.

[29] The US tax credit detailed below was introduced in 1981 by President Reagan with support from the Democrats.

[30] See, for example, Himmelberg and Peterson (1994).

A third major problem relates to the relabelling of other costs as 'R&D' following the introduction of a credit scheme. The rather imprecise definition of R&D adds to this problem. Mansfield and Switzer (1985) argued from survey evidence that reported Canadian R&D expenditures increased by 14 per cent between 1978 and 1982 because of redefinition following the introduction of the credit.[31] Nevertheless, companies have always had an incentive to exaggerate R&D because it is expensed. Relabelling is likely to be a problem primarily at the introduction of the scheme. Government auditors in the US and Australia did not find widespread abuse of the scheme.

While tax credits stimulate new investment, they also subsidise spending that would have taken place in the absence of the credit. To limit the cost and to try to target the credit at 'new' spending, a number of countries have incremental schemes where only R&D above a defined base qualifies for the tax allowance.

The difficulties of designing an incremental scheme are highlighted by Eisner, Albert and Sullivan (1984) and Inland Revenue and HM Treasury (1987). Eisner et al. evaluated the impact of the US tax credit by calculating the value of the marginal effective tax credit (METC). The METC measures the discounted present value of the credit — that is, it accounts for the future stream of marginal benefits that will accrue from the credit.[32]

They found the METC to be very low — on average zero for 1980 and 4 per cent for 1981 — and negative for around one-fifth of firms.[33] This surprising feature of the tax credit arose for three main reasons: the incremental nature of the credit; the company-specific moving-average definition of the base; and the fact that many firms (ranging between 14 per cent and 43 per cent) could not claim the credit due to tax exhaustion.

The incremental nature of the credit meant that if expenditure in a particular year was below the base then no credit accrued in that year. If expenditure was above the base then for each additional R&D dollar spent, a credit of \$0.25 accrued. The credit rate was limited to expenditure up to two times base so that

[31] Canada has made several amendments to the definition of qualifying R&D expenditure in an attempt to minimise the relabelling problem.

[32] Consider a credit rate of 25 per cent. Take a company that is planning to increase its R&D every year over the next three years and stands to enjoy the full credit (i.e. no tax exhaustion or ceiling on the credit). Since the credit uses the nominal value of R&D, increases in R&D will be the rule every year because of inflation. The interest rate is *i*. The METC will be $25(1-\frac{1}{3}\sum_{j=1}^{3}(1+i)^{-j}$. Thus if i = 0.15, the METC is only about 6 per cent.

[33] Negative credits can arise when a firm is considering an increase in its R&D spending that will leave it below the base in its current year, but expects to be above the base in subsequent years. No tax credits will accrue from the increase in R&D in the current year, but the increased base will reduce the size of the credit in subsequent years.

for spending over this ceiling, each additional R&D dollar earned a credit of only $0.125.[34]

However, the important point about the way the base was defined (as a three-year moving average) was that, when a firm increased its R&D expenditure in one year and planned to increase it in the next year as well, then the METC for the next year was reduced by the first year's expenditure because of the increase in the base. Thus the credit was most generous to firms spending more than base in the current year but anticipating no future credits.

Eisner et al. recommended that the credit could be refundable so as not to depend on the firm's tax position, effectively turning the credit into a grant system. Although the US tax credit did not evolve in this direction, the French tax credit has this feature.

In 1991, the base was redefined to be an amount determined by multiplying a firm's 1984–88 R&D/sales ratio by its average annual growth sales over the previous four years. This new definition does not fully solve the problem unless the government is prepared to assume that technological conditions will remain static for the rest of the company's lifetime. Fixing the base at an industry average would be attractive, but then one is faced with the need to locate a multi-industry firm in a particular industry.

Another problem with the implementation of an R&D tax credit is its interaction with other aspects of the tax system. It relies on the company having a tax liability against which the credit can be offset. While there are generally provisions for carry forward of unused credits, their value is significantly reduced since cash tomorrow is not worth as much as cash today.

Altshuler (1988) investigated the incentive effects of the US credit using firm- level tax-return data and incorporated the dynamics of firms' tax positions. This work gave a more detailed picture of the incentives firms faced over time. By 1983, 64 per cent of firms could not fully offset their tax credit and thus had to carry forward their credits, greatly reducing their value. While in 1981 almost three-quarters of qualifying R&D was eligible for a credit, by 1984 the figure had dropped to 54 per cent. The firm-level METCs were highly variable between –11 per cent and +20 per cent. The main conclusion of this work was that when asymmetric taxation was accounted for, the value of the credit was found to be dramatically lower than the headline rate.

Hines (1993a) examined the impact that the tax reforms of the late 1980s had on the location of R&D performed by US multinationals. One aspect of these reforms was to change the rules governing the amount of R&D that can be apportioned to domestic and foreign income. The idea behind the reform was to provide incentives for R&D that was aimed at expanding domestic sales rather than foreign sales. This change affected firms differently depending on their

[34] Other countries have put an absolute cap on how much tax credit a company can receive in a single year — for example, in France the ceiling is FFr40 million.

foreign tax credit position.[35] At the same time, other changes in tax law increased the number of firms in an excess foreign tax credit position. Looking at aggregate data, these changes appear to have had little effect on the amount of R&D done by US multinationals in the US, largely because of the mixed incentives produced by the reforms due to the interaction of various elements of tax law.

VII. IMPACT OF DIFFERENCES IN PRICE

Even when differences in the after-tax price of R&D are observed, it is difficult to determine how sensitive firms are to these prices. The price elasticity indicates the proportional change in the amount of R&D activity in response to a change in the price. Estimates of the own-price elasticity of R&D vary widely. Throughout the 1980s, empirical work had suggested an elasticity of less than –0.5. In other words, a 10 per cent fall in the price of R&D would induce a 5 per cent increase in its quantity. However, more recent studies indicate that the elasticity may be close to, or even less than, –1.0. Table 6 shows some of the estimates that have been obtained using disaggregated data.

TABLE 6

Estimates of Own-Price Elasticity of R&D

Study	*Sample*	*Elasticity*
Bernstein and Nadiri, 1989	US manufacturing firms	-0.4 to -0.5[a]
Nadiri and Prucha, 1989	US Bell telephone companies	Zero
Bailey and Lawrence, 1992	Industry data	-1.0
Hall, 1993	US manufacturing firms	-0.84 to -2.7
Hines, 1993a	US multinationals	-1.2 to -1.8

[a] Note that this refers to an elasticity of the stock of R&D capital with respect to the R&D cost of capital. In the long run, this will be the same as the elasticity with respect to the flow of R&D; but in the short run, if R&D depreciates at less than 100 per cent, the elasticity with respect to the flow of R&D impled by rge estimates will be higher.

One example of the revisionists is Hall (1993), whose work made several advances over previous studies. Her model has a strong grounding in economic theory and explicitly models the behavioural response of companies to changes in the price of R&D. Using data on over 1,000 US manufacturing firms from 1980 to 1991, Hall quantified the impact of the R&D tax credit on the level of investment in R&D. She found that, while the effective credit rate was small, it elicited a strong price response. Her results indicated that additional R&D

[35] US firms can offset against their US tax liability the taxes they have paid to overseas governments on their overseas earnings. This offset is limited to the amount of US tax that is due on that income in the US.

spending of the order of $2 billion per year was stimulated at an annual cost of around $1 billion in forgone tax revenue.[36]

While these estimates are presented with a high margin of error, Hall's work convincingly demonstrates that, over a longer time period, the US tax credit did stimulate some new R&D investment. Hall emphasises the point that the uncertainty over the future of the tax credit coupled with adjustment costs meant that behavioural responses were hard to identify in the early years of the credit. '... the typical manufacturing firm has an enormous incentive to smooth the acquisition of R&D capital, and this greatly inhibits the effectiveness of temporary tax instruments.'

Another form of evidence is survey data — what firms say about the impact of tax rules on their investment behaviour. Mansfield (1986) conducted a survey of top executives in 55 firms in Canada, 40 in Sweden and 110 in the US, asking them to assess the relevance of tax incentives to their R&D spending. He found very small reported increases to R&D as a result of tax incentives (of the order of 1–2 per cent). Although these findings were much in line with Eisner et al.'s (1984) evaluation of the US tax credit, they sit uneasily with the later work of Hall and others. Unfortunately, follow-up surveys have not been attempted for more recent years to determine whether managers' views have changed over time.

There is a more limited amount of information available on the UK and Europe. The Ruding Committee Report (Commission of the European Communities, 1992) included a survey of firms from the EU, asking whether tax was a major factor in locational decisions. Of the 349 responses, over one-third said that tax was always a relevant consideration in the location of R&D centres, 15 per cent said it was always a major factor and a further 25 per cent said that it was sometimes a major factor. These figures compare with over 50 per cent who stated it was always a major factor in the location of a financial service centre and over 20 per cent who said it was always a major factor in the location of production plant.

VIII. CONCLUSIONS

What can be concluded about the desirability of new fiscal incentives for R&D?

First and foremost, one must be clear about whether moves to increase aggregate R&D intensity have real economic justification. There are strong reasons to suspect market failures are endemic due to the difficulties of appropriating the benefits of knowledge. Nevertheless, large countries near the technological frontier, such as Japan, may have more need to invest in R&D than smaller countries further away from the frontier, such as the UK. For smaller

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[36] Similar conclusions were reached in Bailey and Lawrence (1992) and Swenson (1992). GAO (1989), however, found much smaller benefits.

countries, R&D will have a much more important role in speeding the diffusion of best-practice techniques than in generating world-beating innovations.

Even if one is convinced that R&D is 'too low', policymakers need to be clear whether R&D tax incentives are the best method of raising the level of investment. If the problem is primarily an issue of the operation of financial markets or the availability of skilled labour rather than one of spillovers, then policies directed at providing cheaper finance for research or training the labour force seem more appropriate than generalised tax breaks. Knowledge of the causes of underinvestment in R&D is still very primitive and more research needs to be done to establish what are the causal mechanisms.

What has the existing research shown about the effectiveness of tax breaks? The estimates of the costs of conducting R&D in the six OECD countries shown reveal that tax policies provide substantial advantages to R&D vis-à-vis other sorts of investment. The evaluation of the empirical work suggests that the US tax credit experiment in the 1980s was successful in raising the levels of R&D in a relatively cost-effective way. But one must be wary of transplanting US findings directly to other countries.

One of the distinguishing features of the US economy is its sheer size. Other industrialised countries are far more reliant on overseas markets. The R&D performed in the European economies is predominantly by multinationals which may be more sensitive to small changes in the price of R&D between countries. This greater sensitivity could be seen as a boon or a burden. It may mean that the responsiveness of firms in Europe would be even greater than that of their American counterparts. Yet there is a danger that if the main effects of an R&D tax credit is merely to redistribute R&D amongst nations, it will become a globally inefficient 'beggar-my-neighbour policy'. Other countries could retaliate and the usual problems of tax rivalry would emerge.

Important lessons have been learnt from the experience of the US and other countries in the difficulties of implementing a tax credit. Relabelling expenses as R&D remains a problem and some of the extra R&D costs incurred are surely illusory. However, the expensing of R&D in most countries has always given firms some incentive to relabel.

The interaction of R&D allowances with other aspects of the tax system is a key issue, as illustrated by Hines's work. In the UK, the problem of surplus advance corporation tax (ACT), which arises when firms with large overseas interests pay dividends out of their overseas profits,[37] also affects R&D expenditure. This problem provides firms with incentives to shift costs, such as R&D, overseas. For many firms, the negative incentive given by surplus ACT could easily overwhelm any positive impact a domestic tax credit might have,

[37] For further details of surplus ACT issues, see Freeman and Griffith (1993). Surplus ACT can also arise as a result of generous depreciation allowances which lower taxable profits. Steps have been taken to alleviate the former cause of surplus ACT by amending the tax legislation to include a foreign income dividend regime.

especially if the R&D credit must be taken into account before foreign tax credits.

Many countries have R&D tax credits of one sort or another and the recent US evidence suggests that there may be substantial increases in private sector R&D due to such credits. Simply transplanting a US-style scheme has many difficulties including its relocational effects, relabelling and the interaction of the credit with other parts of the tax system. Implementation is far from straightforward, as the experience of other countries has shown, especially with regard to the design of the base where an incremental credit is used. Nevertheless, if policymakers do seek an increase in aggregate R&D, then tax credits appear a feasible and attractive option, albeit one fraught with peril. An internationally co-ordinated response to the problems of R&D would be more in the spirit of tax harmonisation than unilateral action by a single government.

APPENDIX: OVERVIEW OF TAX INCENTIVES FOR R&D IN SIX OECD COUNTRIES

Canada

Taxpayers have the option of deducting qualifying scientific research and experimental development (SRED) expenses or claiming an investment tax credit of 20 per cent of qualifying expenditures. SRED includes both current and capital expenditures (but not on buildings). Where SRED is carried on outside Canada, only current expenditures incurred in the year can be deducted. Expenditure that qualifies for the tax credit includes SRED carried out in Canada, as well as payments to others that undertake SRED in Canada. Unused tax credits can be carried back three years and forward 10 years, or, in respect of certain taxpayers, refunded if unused (subject to certain limitations). A number of provinces in Canada also offer provincial incentives[38] and there are enhanced benefits for Canadian-controlled private corporations.

France

Taxpayers can deduct current expenditure in the year incurred, write off capital expenditure under accelerated depreciation rates, and receive a 50 per cent incremental tax credit (subject to a ceiling of FFr40 million per annum) on the increase in qualifying R&D expenditure over the average R&D expenditure in the preceding two years (adjusted for inflation). For depreciation purposes, scientific or technical research includes activities that have the character of basic research, applied research or development activities. A more limited definition

[38] Quebec, Ontario, Nova Scotia and Manitoba. See Clark, Goodchild, Hamilton and Toms (1993, pp. 32:14–32:15).>

applies for the purposes of the incremental tax credit. Only domestic R&D qualifies for deduction or accelerated depreciation unless the company is permitted to consolidate its accounts, in which case R&D carried out by foreign operations also qualifies. For the purposes of the incremental tax credit, only R&D expenses incurred in France qualify. A reduction in research expenses does not require the repayment of any previous credits, but 50 per cent of the shortfall must be offset against the tax credit obtained in a subsequent year. Unused tax credits may be carried forward three years and, if still unused, refunded in the fourth year.

Germany

No special provisions.

Japan

Current expenditures for R&D can be deducted in the year incurred, or amortised and deducted over a period not exceeding five years. An incremental tax credit of 20 per cent of additional R&D expenditure is available. Qualifying expenditure includes the cost of materials, salaries and wages of employees engaged exclusively in R&D work, and other current expenses, as well as depreciation of machinery and equipment used for such work and amortisation of research expenses. For the purposes of the incremental credit, the expenditure base is defined as the largest amount of expenditure incurred in any previous accounting period since 1966. Several other restrictions apply, such as a maximum credit in any year of 10 per cent of the corporation's tax liability. There are several allowances for accelerated depreciation rates and an alternative fixed-rate tax credit of 6 per cent instead of the incremental tax credit for small and medium-sized enterprises (SMEs).

UK

Current expenses are deductible when incurred. Expenditure of a capital nature on 'scientific research' may be deducted in the year incurred. Scientific research is defined as 'activities in the fields of natural or applied science for the extension of knowledge'. The Inland Revenue adopts a narrow interpretation of what constitutes an 'extension of knowledge'.

US

Current expenditures are fully deductible in the year incurred, although the taxpayer may elect to amortise such expenses over a period not more than 60 months. There are no accelerated depreciation provisions for capital expenditure. Taxpayers can either deduct R&D expenses or claim a federal tax credit of 20 per cent of incremental spending. Qualifying R&D expenses are broadly defined as either qualifying in-house research expenses or qualifying contract research expenses paid to third parties, although only 65 per cent of the latter qualify. Research conducted outside the US is excluded, and there are rules governing the allocation of domestic R&D between domestic and foreign activities so that credit is only given in respect of the former. The expenditure base for the incremental credit is determined by multiplying the company's 'fixed-base percentage' (the ratio of qualifying R&D expenses to gross receipts in the company's taxation years beginning after 1983 and ending before July 1989, to a maximum of 16 per cent) by its average annual gross receipts over the preceding four taxation years. Special rules apply for computing the credit for start-up companies. A number of states offer their own incentives as well.

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