How has Tax Affected the Changing Cost of R&D?

Evidence from Eight Countries

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Summary

This paper describes the evolution of the tax treatment of investment in R&D in Australia, Canada, France, Great Britain, Germany, Italy, Japan and the USA between 1979 and 1994. Estimates of the cost of R&D capital are provided and the methodology used is contrasted with other ones used in the literature. Four findings are highlighted. First, there appear to be substantial differences in the cost of R&D capital across countries at any given point in time. Secondly, there has been a general trend towards more generous tax treatment of R&D, although some countries have moved much more rapidly than others. Thirdly, there is an increasing diversity in the cost of R&D capital between countries, a pattern that is in stark contrast to the convergence in the tax treatment of physical capital. Finally, simulations of the impact of four tax systems on a sample of R&D performing firms illustrates the within-country heterogeneity in the impact of R&D tax credits.

1. Introduction

Throughout the industrialised world, and in the emerging economies of South-East Asia, there has been a general growth in proportion of GDP allocated to privately funded research and development (R&D) activities (see Figure 1.1). Although there is controversy surrounding the causes of this phenomenon and the reasons why some countries have experienced faster growth than others, it is commonly agreed that industrial production and global competition are increasingly based on the introduction of new technologies.[1] In parallel with this empirical development, theorists of economic growth have formalised Schumpeter's notion that investment in intangible assets (such as R&D and human capital) is *the* crucial factor in generating faster rates of output growth.[2] R&D is likely to be under provided in market economies for a variety of reasons. Most famously, R&D generates new information and information is a partially non-rival good. In the absence of a perfectly functioning patent system, this will lead to socially sub-optimal levels of R&D. Imperfections in other markets, which provide complementary assets to R&D, will reinforce this problem. For example, low levels of training or poor access to financial markets will tend to have a depressing effect on R&D investment.[3]

Given these empirical and theoretical developments it is not surprising that policy makers have become concerned with the impact of the tax system on the economy's innovative capacity. In particular many countries have turned to ex-

[1] See Van Reenen (1996).

[2] See, *inter alia*, Aghion and Howitt (1992), Grossman and Helpman (1991).

[3] For evidence of failures in the market for skills see Booth and Snower (1996); for evidence of failure in credit markets for R&D see Himmelburg and Peterson (1995).

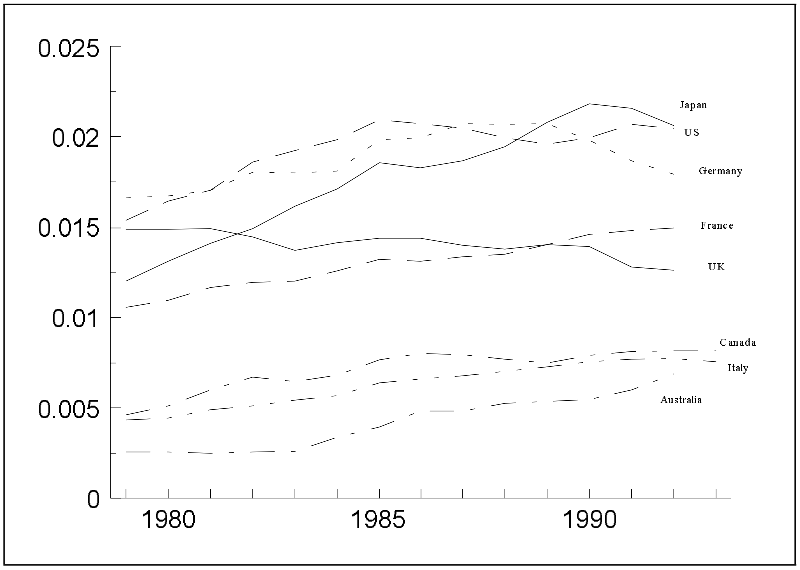

Figure 1.1: Business expenditure on R&D as proportion of GDP

plicit fiscal incentives to encourage R&D investment. The current wisdom on the impact of these fiscal incentives, based primarily on single country studies, usually the United States, is that the effects could be substantial. This paper takes an international approach examining eight major industrialised countries (Australia, Canada, France, Germany, Italy, Japan, the UK and the USA). We extend previous cross-country studies by examining the evolution of the effects of the tax systems in these countries over a sixteen year period (1979-1994).

The methodology used in this paper is an extension to R&D expenditures of the King and Fullerton (1984) approach to calculating the effects of tax on the costs of physical capital. It is a useful method of summarising the influence of different parts of a complex tax system into a single, quantitative measure. The cost of R&D capital across countries estimates the extent to which different countries subsidise or penalise R&D investments relative to a no-tax regime. This enables valid cross-country comparisons to be made. Calculating such measures is a novel exercise which provides a valuable data resource for future researchers. A substantial part of the paper is therefore devoted (in Appendix A) to a careful documentation of this methodology and a critical comparison with the existing approaches. For similar reasons, Appendix B gives summary details of the tax treatment of R&D expenditures in different countries. The effects of tax on the cost of R&D are illustrated in two ways in this paper. First, we calculate the cost of R&D capital for a 'representative' firm earning the full amount of credit to capture the upper bound of the effects of R&D tax credit systems. This measure does not, however, reflect the heterogeneous way the tax system can affect firms. To illustrate this variety the impact of four of the tax systems are simulated on a sample of firm level data. However, we do not attempt the more complex task of examining what the *effects* of changes in the cost of capital are on the actual amount of R&D performed.[4]

The structure of this paper is as follows. Section 2 outlines the approach taken to measuring the cost of R&D capital in this paper; section 3 briefly summarises previous studies. Section 4 describes the general trends in tax systems and the tax treatment of R&D over the 1980s and 1990s. In Section 5 some simulations of the effects of different tax systems are performed and some concluding comments offered in Section 6. To pre-empt our conclusions, the key findings are that: (i) there is substantial variation in the cost of R&D between countries; (ii) there exists a general downward trend in these costs, (iii) variation in the cost of capital

[4]See Hall (1995) or Griffith, Sandler and Van Reenen (1995) for critical surveys of studies examining these effects.

increased over the period; (iv) the design and implementation rules of R&D tax credits can have a large impact on the distribution of effective tax rates on R&D.

2. Measuring the Cost of R&D Capital

This section lays out the methodology used to calculate the impact of the tax system on the cost of R&D capital. This methodology was developed in King and Fullerton (1984) and used in OECD (1991). The idea is to derive a single quantitative measure to summarise the effects of a complex set of tax regulations on the cost of performing R&D. This is the pre-tax real rate of return on the marginal investment project that is required to earn a minimum rate of return after tax.[5] It will be a function of the general tax system, economic variables and the treatment of R&D expenditure in particular. To focus purely on the tax effects, economic variables such as inflation and interest rates are held equal across countries.

The details of the calculation are briefly given here and detailed in Appendix A. Consider an investment project with a present discounted value of

$$V = \frac{p\,(1-\tau)}{\rho + \delta - \pi}$$

where p is the rate of return, τ is the statutory tax rate, δ is the economic depreciation rate, ρ is the firm's discount rate and π is the rate of inflation. The discount rate is the rate of return that is just sufficient to satisfy the providers of capital. It will depend on the form of finance used in both the parent and the subsidiary. When the investment in R&D is financed by retained earnings, and

[5] In this paper we assume a real hurdle rate of return of 5%.

the marginal investor is tax exempt, the discount rate is equal to the nominal interest rate, i.

The initial cost of the investment, net of tax, is unity and after tax is defined by,

$$C = 1 - A$$

where A is the net present discounted value of depreciation allowances and tax credits on the assets. For the marginal project, where the net present value is equal to the cost, the minimum required pre-tax rate of return[6] is given by:

$$p = \frac{(1-A)}{(1-\tau)} (\rho + \delta - \pi) . \tag{2.1}$$

The cost of R&D capital in the absence of tax is given by the real interest rate (r). Below we present calculations of the tax wedge which is the additional return needed to cover taxes and is given by $p - r$.

2.1. Previous Work

Previous empirical work that has measured the impact of tax on the cost of R&D capital has largely examined the evolution of the US R&D tax credit. This was introduced in the Economic Recovery Tax Act of 1981 and subsequently reformed several times. One of the most studied features of this tax credit has been the impact that the way in which incremental spending is defined has on the effective value of the credit. For most of the life of the credit the base has been defined as spending above the average of the previous three years spending. A pioneering

[6] Note that this is different than the King-Fullerton approach where the minimum required pre-tax rate of return is considered net of economic depreciation so $p = \frac{(1-A)}{(1-\tau)} (\rho + \delta - \pi) - \delta$.

study by Eisner, Albert and Sullivan (1984) evaluated the impact of the tax credit using a measure of the marginal effective tax credit (METC). They highlighted the fact that the net present value of the credit was substantially less than the statutory rate. The METC measures the discounted present value of the credit on an extra unit of R&D - that is, it accounts for the future stream of marginal benefits that will accrue from the credit. Although the statutory rate of the credit was 25 per cent, 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. A negative METC 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. 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.

In a study using firm level tax return data Altshuler (1988) examined the impact of the US tax credit, taking into account the dynamics of the firm's tax position. Her main finding was, for companies with no tax liability, the necessity of carrying forward non-indexed credits and the discounting of future returns dramatically reduced the incentives provided by R&D credits. A large number of firms were in this position: in 1981 nearly three-quarters, although this had dropped to just over one-half by 1984. Hall (1993) extended Eisner et al.(1984) by calculating a measure of the after tax price of R&D, θ_t, which included a value of the depreciation allowances, as well as tax credits. Her estimates showed the considerable heterogeneity of the METC facing her sample of about 1,000 firms, both at a point of time and over time. She concluded that one of the significant advantages of moving to a fixed based scheme in the 1990s was the reduction in this variation in the tax price facing different U.S. firms.[7]

There are several studies which have made international comparisons. Leydon and Link (1993) provide some descriptions of different tax systems and Hall (1995) offers a more comprehensive evaluation. Neither give cost of capital estimates, however. Warda (1994) examined 11 countries (and regions within the US and Canada) using a slightly different measure, the B-index, to measure and rank the relative cost of R&D. The B-index yields the present value of before-tax income necessary to cover the cost of an initial R&D investment and to pay the applicable income taxes so that an R&D project becomes profitable for the firm that undertakes it (see Appendix A). Griffith, Sandler and Van Reenen (1995) present calculations of the cost of R&D capital for the G7 countries. None of these studies examine trends or changes over time. All of the international comparisons make the common point that tax systems have large effects on the implied costs of capital, at least at a point of time. We use the results and rankings from these other studies as a check on the results reported here.

3. Trends in the Cost of R&D Capital

Reforms of capital taxes over the past decade have tended to lower statutory rates and broaden the tax base. There has been some convergence in effective marginal

[7] Other important studies include Hines (1994) who adapted Hall's method for multinational firms taking into account the impact of foreign tax surpluses. He also found large responses to the tax-induced fall in the cost of R&D capital. Also, Mansfield (1986) adopted the Eisner approach to Sweden and Canada.

tax rates on capital. At the same time there has been much discussion about the potential gains from harmonisation of tax rates and tax systems, especially within the European Union.[8] What has happened to the tax treatment of R&D? This section documents general trends in the tax treatment of R&D in the eight countries over the period 1979 to 1994 (Appendix B gives more detail about each country). It is worth noting that the cost of R&D capital reported here is for a fully qualifying R&D investment where the amount of credit is not constrained by any capping rules and the firm has sufficient tax liability against which to offset the credit. Thus, the figures reported here can be thought of as the upper bound of the value of universally available credits.

The parsimony of our approach to measuring the cost of R&D capital comes at a methodological cost. It is not really possible to do justice to the heterogeneity of the effects of fiscal incentives across firms. First, there are various specially targeted schemes on small and medium size enterprises, particular industries and particular regions (within a country). Secondly, the credits are capped at different levels. Thirdly, firms are in different tax positions and these interact with loss carry forward and carryback positions in complex ways. These are not modelled in this paper, except for a partial attempt in the next section (to do this thoroughly one would need firm level data over time in each country on a consistent basis).

The following assumptions are made concerning the type of investment to be analysed. We consider a domestic investment, financed from retained earnings, in the manufacturing sector and divided into three types of asset for use in R&D - current expenditure, buildings, and plant and machinery. An important assumption in the modelling strategy used here is that current expenditure on R&D is

[8] See, for example, Ruding (1992) and Devereux and Pearson (1995).

treated as an investment - that is, its full value is not realised immediately but accrues over several years.[9] Current expenditure on R&D is assumed to depreciate at 30% a year, buildings at 3.61% and plant and machinery at 12.64%.[10] It is also assumed that tax changes are not anticipated and that firms expect the current tax system to continue into the indefinite future (see Appendix A for some further discussion of this assumption).

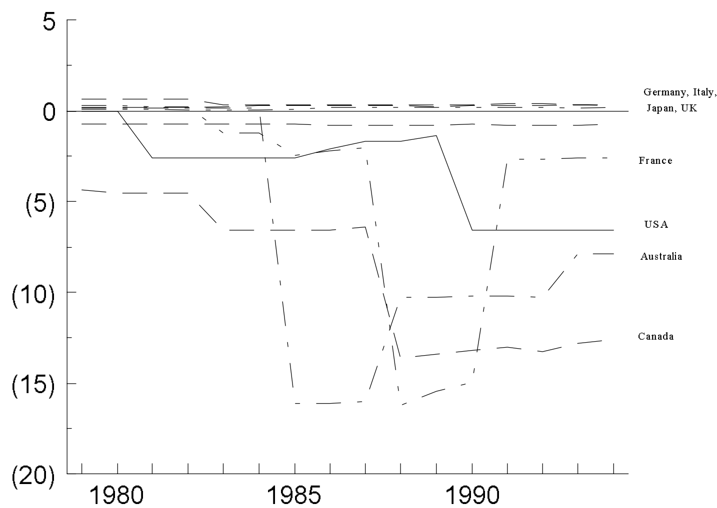

Figure 3.1: Tax Wedge in all countries

Figure 3.1 shows how the tax treatment of R&D has changed over time. This graph shows the tax wedge (this is the difference between the rate of return that must be earned before and after tax) on a typical R&D investment. The wedge is

[9] To examine the differences in the tax wedge across different types of assets the King-Fullerton measure, net of depreciation, is more informatative. The extent to which investment in these assets is taxed or subsidised is, in part, determined by the degree to which depreciation rates allowed by the tax system differ from the economic depreciation rate.

[10] The depreciation rates for buildings and plant and machinery are taken from OECD (1991). In most empirical work it is between 15%-30%: see the survey in Mairesse and Sassenou (1991).

weighted across assets (90% current expenditure, 3.6% buildings, and 6.4% plant and machinery[11]). Inflation and interest rates are held constant across time and countries in order to emphasise the differences in tax systems. Taking any year in isolation, it is clear that there exist large differences between countries, these have been highlighted in previous studies.

Overall, there is a downward trend in the cost of R&D capital, with the mean value falling from a subsidy of just under one half a per cent in 1979 to just over three and a half per cent in 1994. Nevertheless, there is a clear division between countries: four have very generous systems (Australia, Canada, France and the US), and four have much less generous regimes. Consequently, Figures 3.2 and 3.3 split the countries into these two groups.

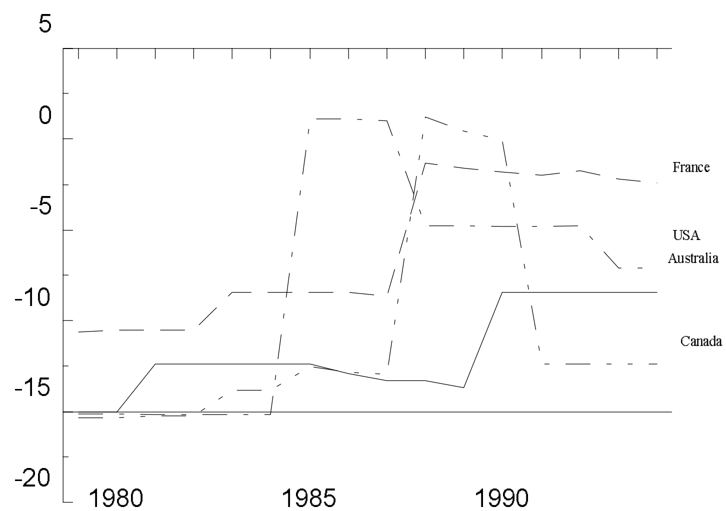

Figure 3.2: Tax wedge in the four most generous countries

[11]Figures taken from OECD (1991) and UK Economic Trends (1996).

Turning first to Figure 3.2, it appears that Canada has the most generous treatment of R&D, except during three years in the mid 1980s when Australia gave a larger subsidy. Furthermore, in all of these countries the tax treatment of R&D has become *more* generous since the early 1980s, although there has been considerable turbulence in the cost of R&D capital. Countries move in their relative position and there are substantial changes in the tax wedge on R&D due mainly to changes in tax policies. The mid to late 1980s was a period of particular change. This turbulence does illustrate the problem that for firms considering their long term investment plans, there may have been considerable uncertainty about the permanency of fiscal incentives.[12]

The reasons that account for the periods of large change in the cost of R&D capital vary across countries. In Australia the large drop in 1985 was caused by the introduction of the 150% 'superdeductibility' of R&D. The subsequent increase was due to the lowering of Australia's statutory rate of corporation tax. The generosity of the Canadian system is driven by the fact that the credit rate is relatively high (50%) on the incremental amount of R&D. The fall in the cost of R&D capital in 1988 was precipitated by the introduction of a second credit in Ontario (the Province we model here). In France the introduction of the credit in 1983 had much less effect than the redefinition of the base (from a moving to fixed base and then back again) which occurred between 1987-1990. Similarly in the USA, the base re-definition in 1990 had much more effect than the introduction of the credit in 1981. What is illustrated here is that the statutory credit rate is not of over-riding importance to the cost of R&D capital. The design and

[12] Hall (1993) emphasises that companies may have been reluctant to commit themselves to large changes in their R&D programmes in the early years of the US credit due to worries about its longevity.

implementation of the schemes (such as the definition of the base) and the effects of other parts of the tax system (such as the statutory tax rate) are at least of equal importance in explaining the time series trends.

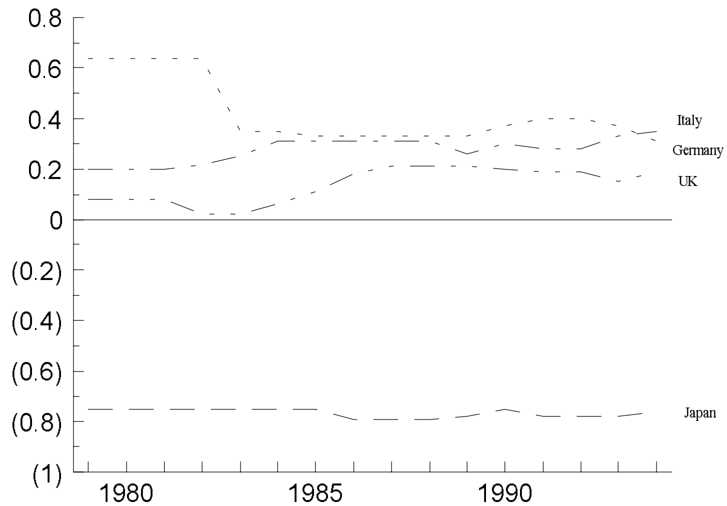

Figure 3.3: Tax wedge in the four least generous countries

Figure 3.3 shows the tax wedge in the four less generous countries. In these countries the tax systems are broadly neutral to R&D (i.e. the tax wedge is close to zero). There have not been many changes the tax treatment of R&D in these countries over this period. Japan occupies a somewhat intermediate position, however, as it is amongst the more generous countries in 1980, but has had a broadly stable system. Japan is the only country in this group which has an R&D tax credit.[13]

[13] Note that Japan gives a range of additional tax credits for specific types of R&D. For example, small and medium sized firms can elect to receive 6% of total expenditures as a credit (limited to 15% of the firm's tax bill). Additional R&D tax credits are also available for: (i)

Another striking feature of Figure 3.1 is the fact that the range of the tax wedges at the end of the period is greater than at the start. In 1979 the mean effective marginal tax wedge on the typical R&D investment was -0.5 with a standard deviation of 1.6. By 1994 the mean had fallen to -3.7 and the standard deviation increased to 4.8. This contrasts strongly with the tax wedge on the typical investment in physical capital which has shown a tendency towards convergence over this period.[14] For example, in 1979 the average tax wedge on physical investment was 3.1 with a standard deviation of 1.8. By 1994 this had fallen to a mean of 2.6 with a standard deviation of 1.2. The fall is more dramatic if we consider the G7 (excluding Japan). In 1979 the mean was 2.7 with a standard deviation of 1.9, falling by 1994 to 2.4 with a standard deviation of 0.73.

How sensitive are the estimates of the cost of R&D capital to the assumptions underlying the calculations? The results are not sensitive to changes in the appropriate rate of depreciation for R&D capital - a variable for which there are few reliable estimates. For example when the rate is changed from 30% to 15% the main features of Figure 2 remain the same.

Recall that in Figures 3.1 to 3.3 we have been considering a typical R&D investment, which is 90% current expenditure. Current expenditure of any sort is fully deductible in all countries which means that only subsidies through tax credits and superdeductibility affect the tax wedge for this asset. However, expenditure on plant and machinery and buildings are not fully deductible, therefore, depreciation allowances have a significant impact on the tax wedge for these assets. The different rankings of the tax wedge on these assets mirror those found with

investment in promotion of basic technology - 7% of total expenditure; (ii) R&D carried out in cooperation with government - 6% of total expenditure.

[14]For a more detailed discussion of this issue see Griffith (1996).

investment in physical capital - current expenditure is treated most favourably, plant and machinery next and buildings least.

The tax wedge varies significantly with the type of financing for investment in R&D, as it does with investment in physical capital. However, survey evidence strongly confirms that R&D is overwhelmingly financed from internal earnings.[15] Different assumptions about the rates of interest and inflation would also change the tax wedge, however, the overall patterns and conclusions remain the same.

4. Simulations

The tax wedges presented above do not reflect the substantial heterogeneity in the marginal tax rates that different firms face. For example, the impact of the various capping rules are not incorporated into the tax wedge. Furthermore, the cost of R&D capital is not informative about the scale of likely revenue costs relative to the amount of new R&D we might expect to be generated. This section attempts to address these two issues. In order to illustrate the differential way in which these credits will impact on firms, we have simulated four of the tax credits using a sample of R&D performing firms.

A sample of 244 firms were taken from the UK Stock Market. Since the tax system in the UK has always been broadly neutral with respect to R&D spending the data seem a good baseline case. Data on the amount of R&D undertaken, sales, and tax liability is taken from the published accounts for the years 1989 to 1993. The various tax systems are then applied to these firms, as described below. This sample is biased towards larger firms,[16] with median sales in 1993 of £126

[15] See the evidence cited by Mayer (1992).

[16] For data requirement reasons we use only firms that have been listed on the Stock Market

million. R&D is highly concentrated, much more so than sales. In 1993 the top 20 largest R&D firms account for 69% of all R&D in the sample. The equivalent number for sales is 48%. The R&D to sales ratio does not vary across firm size.

The revenue and first round investment effects of the tax credits are simulated in the four countries that treat R&D investment most favourably. The amount of R&D reported in company accounts is treated as the amount of R&D the firm does in the absence of tax. The elasticity of R&D with respect to price is assumed to be -1, as recent econometric studies have commonly found values around this number.[17] Firms can offset the credit up to the amount of tax liability they report in their accounts. The method for calculating the marginal effective credit rate is as described in Appendix A. Details of the tax treatment of R&D are given in Appendix B. The main features that are modelled are:

- Australia: 150% depreciation allowance on total expenditure; minimum threshold.
- Canada: 20% national credit on total expenditure; 37.5% Provincial (Ontario) credit on incremental expenditure, base defined by three-year moving average of past R&D.
- France: credit on *real* incremental spending of 50%; base defined by two-year moving average of past R&D; absolute cap of £4m.
- USA: 25% credit on incremental expenditure; base defined by three-year moving average of the R&D to sales ratio; proportional cap of 0.16 R&D to sales ratio.

for five continuous years.

[17]For example, Hall (1993) and Hines (1994).

The numbers reported in Table 1 show the impact of different credits when applied to firm level data for 1991.[18] Under the Canadian system all firms would be eligible for some credit. Under the Australian system nearly all firms in our sample would be eligible, whilst under the French system only 83% would be eligible and under the USA system only 77% would. This is a function purely of the rules of the credit. The next row accounts for the tax position of the firm and shows the proportion of firms that received the full credit. Those which did not receive the full credit did not have sufficient tax liability in that year against which to offset their credit. Clearly, the proportion who receive the full credit rate is lower: about 72% in France and 75% in the USA.

Even for those firms who receive the full credit, the marginal effective tax credit (METC) can be well below the statutory rate. This is particularly true for incremental credits where the base is defined as a moving average. This can be seen in the average METC for Canada and France (weighted by R&D). In France the average METC was only 4%, compared to a headline rate of 50%. This vividly illustrates the effects of the moving average base.

[18] Except for the USA where 1992 is used because of the need for a three-year base. For Canada the base is approximated by a two year moving average.

Table 1: Simulations of R&D Tax Credits in Four Countries

	Australia	Canada	France	USA
Proportion of (244) firms doing R&D:				
eligible for credit[19]	100%	100%	83%	77%
receiving full credit	84%	72%	72%	75%
Statutory tax credit rate				
average METC (weighted by R&D)	9%	14%	4%	17%
Concentration measure				
% of revenue going to top 5 firms	52%	45%	11%	59%
Revenue cost (£ million)	1,158	2,145	186	188
New R&D spending(£ million)	620	598	34	154

The distribution of tax credits paid out to firms is different across the various systems. This is summarised in the concentration measure, which is the percentage of total credit paid going to the firms getting the five largest credits. Because R&D is very heavily concentrated, unless the credit is capped, the benefits go disproportionately to the larger firms. Under the Australian and USA systems the top five firms alone get more than half of the amount of credits paid out, while in Canada they get just under half. Where a credit has an absolute cap, as under the French system, the distribution of the credit is much more skewed to smaller firms. The largest five get only 11% of the amount of credit paid out. This low cap was an explicit policy of the French government which sought to encourage more innovation amongst smaller firms.

The final rows of Table 1 give estimates of the revenue cost and of the expected

[19] The figure for Australia is 99.6% because one firm falls below the £5,000 R&D threshold.

amount of new R&D spending that would be generated by the credit. Given that we have assumed an elasticity of -1 these two numbers differ because firms are tax exhausted or have hit the limit of a cap, and therefore their METC is zero, or because the moving average definition of the base has reduced their METC. The Australian and Canadian systems are significantly more costly than those in France and the USA. Nevertheless, the USA scheme generates $0.82 of R&D for every $1 lost in tax revenue, which is higher than any of the other systems. The French system appears to be particularly poor at generating new R&D given its cost to the state.

None of these simulations should be taken as definitive given the strong assumptions underlying them and the particular sample of firms used. Nevertheless, they do illustrate that the impact of tax schemes varies substantially between companies. They also indicate the general order of magnitude of the costs and benefits of different systems.

5. Summary and Conclusions

Despite the widespread concern that policy makers and economists have expressed over the amount of innovative activity undertaken, quantitative assessments of technology policies across countries are rare. In this paper we consider the effects of tax systems on the cost of R&D capital in eight countries over sixteen years. An important feature of many of the main industrialised countries is the generous treatment of R&D compared to other forms of investment. Previous studies have only considered the time series profile of one country or international comparisons at one point of time. The numbers presented here reveal several interesting patterns. First, as other studies have found there is considerable variation in the cost of capital between countries at any point of time, even holding inflation, depreciation and interest rates constant across nations. Secondly, there is a discernible trend towards more generous tax treatment of R&D in half the countries in our sample. Thirdly, of those countries which changed there is a lot of turbulence in the cost of capital: the changes were not smooth.

Why do we see this increase in diversity in the taxation of intangible assets, but not in physical capital? One reason might be that there exists a greater diversity of opinion on what the optimal tax treatment of intangibles is. Some countries believe a strong R&D base is a way of improving competitiveness. Evidence of international spillovers has led others to argue that a large domestic R&D base is no longer necessary for economic growth and therefore there is no reason for governments to provide substantial subsidies for R&D. Thus policy-makers differ in their opinions over what the appropriate role for the state should be in encouraging R&D, and this is reflected in different national tax policies.

The reasons for the turbulence were country-specific, but were not all due to changes in the tax credit rate. More typically large changes were due to changes in the way the base was calculated or due to changes in other parts of the tax system. To address the issue of heterogeneity in the cost induced by different tax positions and capping a simple simulation exercise was carried out. This illustrates the degree to which the benefits of tax credits are usually highly concentrated amongst a few firms.

What is described in this paper is essentially a panel of countries with data on changes in the cost of capital induced by policy experiments. We have seen that there is considerable heterogeneity between countries over time. Such changes, if exogenous, give researchers a rare opportunity to exploit the effects of tax-price variation on capital demands[20] - for R&D as well as other intangible and tangible investments.

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[20] See Cummins, Hasett and Hubbard (1996) for an example of this with respect to physical capital.

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A. Measuring the Net Present Value of Allowances and Credits

The net present value (NPV) of depreciation allowances and tax credits is given by

$$A = \tau A_d + A_c \tag{A.1}$$

where A_d is the net present value of depreciation allowances and A_c is the net present value of tax credits. The value of A_d depends on the depreciation rates allowed and whether depreciation is using the straight line or declining balance method.

There are several types of tax credits available on R&D expenditure. The main features of these credits are whether they apply to total or incremental expenditure and how the base expenditure is defined in the incremental case. The net present value of the credit is given by

$$A_c = (1 - D_c \tau)\, \tau^c.$$

where D_c is the proportion of R&D that is deducted from taxable income, τ is the statutory corporate tax rate and τ^c is the statutory credit rate.

Where credits apply to incremental expenditure the NPV depends on how the base is defined. The definitions of base that are made in the eight countries are: (i) last year's expenditure, (ii) the previous largest expenditure, (iii) a fixed year in the past, (iv) an average of the last two years' expenditures, (v) an average of the last three years' expenditures. All of these can be in real or nominal terms. We model (i) and (ii) as the same and assume that (iii) has no impact on the net present value of the credit.

Under the assumption of positive current and expected future growth in R&D spending, the net present value of the incremental credit is given by,

$$A_c = (1 - D_c \tau)\, \tau^c \left[1 - \frac{1}{k} \left(\Sigma_{k=1}^{K} (1 + r)^{-k} \right) \right]. \tag{A.2}$$

where K is the number of years over which expenditure is averaged to define the base, and r is the discount rate. If the credit is on real expenditure (as in France) then A_c is divided by $(1+\pi)$.

How does (A.2) compare with the more well known approaches in the literature? First, consider the marginal effective tax credit (METC) calculated by Eisner et. al. (1984). For an uncapped firm this is given as:

$$METC = \tau_c(1 - \frac{1}{3}(1+r)^{-1} - \frac{1}{3}(1+r)^{-2} - \frac{1}{3}(1+r)^{-3}) \tag{A.3}$$

where τ_c is the rate of credit and r is the firm's discount rate. Which is identical to A_c if D_c =1.

Secondly, Hall (1993) measured the after tax price of R&D using the formula

$$\theta_t = p_t^r(1 - T_t(1+r)^{-j}\tau_t - \eta_t ERC_t) \tag{A.4}$$

where p_t^r is the price of R&D investment in the absence of taxes, T_t is a dummy that indicates whether a firm has taxable income in the current year, r is the firm's discount rate, j is the number of years before any loss carryforwards will be exhausted (usually equal to zero), τ_t is the corporate tax rate, η_t is the share of qualified R&D expenditure, and ERC_t is the effective rate of R&E tax credit. The ERC_t is computed using a similar formula to the Eisner's METC (equation(A.3)), suitably modified to take account of changes in the tax law since 1984. Hall's measure θ_t is equivalent to the value $1 - A_c$ if p_t^r is scaled to one and the firm is assumed to have a sufficient tax liability in all years against which to offset the credit.

Finally, an alternative measure called the B-index was used by Warda (1994) among others. This is the critical (minimum) before tax benefit/cost ratio. The formula for the B-index is,

$$B = \frac{ATC}{(1-\tau)}$$

where ATC is the after tax cost of \$1 of R&D and τ is the statutory tax rate.

Hence, the investment is profitable if,

$$\frac{V_{pretax}^{j}}{C_{pretax}^{j}} \geq B$$

where V_{pretax}^{j} is the pre-tax present discounted value of revenues from a project of size j and C_{pretax}^{j} is the pre-tax cost of a project of size j. Standardising this for a project of unit cost (dividing by the value of j) the investment is profitable if,

$$V_{pretax} \geq B$$

which is equivalent to,

$$V_{pretax} \geq \frac{(1-A)}{(1-\tau)}$$

which can be rearranged to produce,

$$V \geq C$$

where $V = (1-t)V_{pretax}$ and $C = 1 - A$ (from below). Enforcing equality and rearranging to derive p the rate of return, as the left hand variable (as a function of A, t, r, δ, and π) would produce the King and Fullerton (1984) fixed-r equation used in our calculations. The Warda B-index where ATC is the after tax cost of \$1 of R&D is equivalent to the value $1 - A$ in equation (A.1).

There are several criticisms common to these measures. First, the exact definition of 'qualifiable R&D' differs across countries. In the U.S., for example, the part of R&D designated for enhancing foreign sales was treated differently from the rest (see Hines, 1994). Secondly, the value of the credit will also depend on whether or not the credit is capped. In some countries there are absolute caps while in others there are proportional caps. It is assumed that the investments fall between any maximum caps or minimum expenditure thresholds. Thirdly, in calculating the tax wedge we have assumed that firms are expecting their R&D to grow. If firms where planning to hold or cut their R&D investment the cost of capital would differ due to the definitions of the base, as illustrated in the simulations.

A final difficulty relates to the role of expectations. We are assuming firms expect the current conditions to last indefinitely. One difficulty is that firms may anticipate a tax change (indeed, it may be preannounced), or they may anticipate a revision of the definition of the base in the future. Even if the base is fixed, some revision will eventually occur unless the tax credit is scrapped. Thus, the future base may be linked in some way to current expenditure, and current R&D will be expected to have some impact on the future base. Since the R&D expenditure bases have historically been revised every three or four years on average, this could lead to frequent and large variations in the incentives to undertake R&D by forward looking firms. Judging by the cycle of base revisions over the 1980s in France and the USA, firms in both countries may be expecting an impending revision of the current base and be acting accordingly.

B. Tax Data

This appendix details the tax treatment of expenditure on R&D in eight OECD countries. The tables under each country section give the statutory tax rate on retentions and the net present value of depreciation allowances and tax credits on the three R&D assets considered. The figures show the tax wedge on investment in each of the three assets.

The statutory tax rates shown below are on retained earnings and are based on the rates in force as a result of any change in that calendar year. For example, if the tax rate falls from 35% to 33% on the 31 March 1993, the rate for 1993 is given as 33%. If two changes occurred in one year then only the final change is recorded. The statutory tax rate includes surcharges or other special taxes that are levied on corporate income at the national level. Where a tax on corporate income is levied at a local level, for example by states or provinces, we have tried to construct an average of these rates to indicate the average additional tax at the local level. This has not always been possible and in several cases the local tax rate is set at the 1991 rate in every year due to lack of information. Where there are local credits on R&D expenditure we have generally taken the most generous. Local taxes only include local corporate income taxes. In general they do not include taxes on property. In many countries local taxes are deductible from the national tax and this is taken into account.

Most countries allow a wide range of depreciation methods and rates. We have, in general, used the most favourable method and rates that are commonly allowed on the various classes of asset. The two most commonly used methods are straight-line (SL) and declining balance (DB) depreciation. In addition, many countries give extra first year allowances or provide accelerated depreciation allowances in the first few years. In general plant and machinery is depreciated using the DB or a combination of DB and SL methods, while buildings are depreciated using SL.

The figures shown in tables below are the net present value (NPV) of these depreciation allowances, which combines the stream of deductions from taxable income the allowances represent with the statutory tax rate, to produce the current value of these allowances to the company. They are expressed in terms of the present value of the future stream of depreciation allowances on an investment of 100 units of local currency.

For illustrative purposes these NPVs are calculated using a common discount rate to abstract from differences in inflation (using 4.5% inflation and a real interest rate of 5%). Where depreciation rates are based on unspecified asset lives we assumed that plant and machinery has a useful life of 8 years and buildings of 25 years.

B.1. Australia

Australia introduced a special 150% depreciation allowance for qualifying R&D in 1985: 150% of current expenditure can be written-off in the first year, plant over three years, and buildings over 40 years. This dramatically reduced the tax wedge on current expenditure and plant and machinery R&D (as shown in Table 1), providing a large subsidy for R&D expenditures. This special depreciation allowance did not affect the tax wedge on buildings used for R&D as much, since a rapid three year depreciation provision was already in existence. Qualifying R&D included expenditure on innovation or projects that involved technical risk, and was carried out in Australia for the benefit of Australians. Australia is unusual in that it has a minimum threshold of A$50,000 to receive the full 150%, with a sliding scale between A$20,000 and A$50,000, and no additional allowance for expenditure below A$20,000. The fall in the overall tax subsidy in 1988 reflects the cut in the statutory tax rate on retentions from 50% to 39% which reduced the value of the additional R&D depreciation allowance.

Table B.1. Australia

Year	Statutory Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	50	0.50	0.46	0.45
1980	50	0.50	0.46	0.45
1981	50	0.50	0.46	0.44
1982	50	0.50	0.46	0.44
1983	50	0.50	0.46	0.44
1984	50	0.50	0.46	0.44
1985	50	0.75	0.46	0.69
1986	50	0.75	0.46	0.69
1987	50	0.75	0.35	0.70
1988	39	0.58	0.25	0.54
1989	39	0.58	0.25	0.54
1990	39	0.58	0.17	0.54
1991	39	0.58	0.17	0.54
1992	39	0.58	0.25	0.54
1993	33	0.50	0.21	0.45
1994	33	0.50	0.21	0.45

B.2. Canada

Canada allows full deduction on current expenditure, expenditure on plant and machinery for R&D purposes throughout the period and for R&D buildings from 1979 to 1987. A national Scientific Research Credit of 50% on incremental expenditure above the average of the previous three years was also provided during 1979 to 1982. This was replaced by the national Investment Tax Credit (ITC) of 20% of total R&D expenditure, which fully reduces the cost of the asset for deduction purposes. We have modelled the provincial credits available in Ontario as they are some of the most generous. This includes a 25% superallowance on all expenditure that qualifies for the national credit, minus the amount given for the national credit. This has the impact of nullifying the reduction in the 100 per cent write off due to the reduction of the deductible costs by the value of the credit. In addition, Ontario gives a 35.7% credit on incremental expenditure. Incremental expenditure is defined as additional spending about the average of the past three years expenditure. The value of the these credits and deductions are shown in Table B.2.

Table B.2. Canada

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	30.0	0.51	0.51	0.51
1980	31.8	0.53	0.53	0.53
1981	31.8	0.53	0.53	0.53
1982	31.8	0.53	0.53	0.53
1983	30.9	0.55	0.55	0.55
1984	30.0	0.55	0.55	0.55
1985	31.8	0.56	0.56	0.56
1986	31.8	0.56	0.56	0.56
1987	29.1	0.54	0.18	0.54
1988	26.8	0.65	0.15	0.65
1989	25.8	0.64	0.12	0.64
1990	24.8	0.63	0.12	0.63
1991	23.8	0.62	0.12	0.62
1992	23.8	0.64	0.12	0.64
1993	22.8	0.61	0.11	0.61
1994	21.8	0.60	0.11	0.60

B.3. France

In 1983 a 25% tax credit was introduced on the real increase in qualifying R&D expenditure over last year, with a FF3 million per year cap. This led to a small fall in the tax wedge (as shown in Table 3). The credit rate was increased to 50% in 1985 and the cap raised to FF5 million, leading to a further fall in the marginal tax wedge. In 1988 firms were given the choice between the a 50% credit on the increase over the previous year's expenditure, with a maximum of FF5 million (increased to FF10 million in certain cases). Alternatively, for the years 1988, 1989, and 1990 they could get a 30% credit on the increase over their 1987 expenditure, up to a maximum of FF3 million. This latter option is worth more to firms expecting to increase their R&D spending and is what we model. Although the headline rate of credit fell (from 50% to 30%) the value of the effective subsidy to R&D increased sharply because the base used to calculate the increase in R&D expenditure was fixed at the 1987 level eliminating the impact of current R&D spending on the calculation of the future base. In 1991 the credit returned to 50% on the increase in real expenditure, but the base was extended to the most recent two years and the cap raised to FF40 million. This reduced the effective value of the subsidy due since the base was changed back from a fixed base to a moving average. From 1983 to 1986 expenditure on buildings used for scientific research was given an accelerated depreciation allowance of 50% straight line.

Table B.3. France

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	50.0	0.50	0.25	0.43
1980	50.0	0.50	0.25	0.43
1981	50.0	0.50	0.25	0.47
1982	50.0	0.50	0.25	0.46
1983	50.0	0.52	0.50	0.48
1984	50.0	0.52	0.50	0.48
1985	50.0	0.54	0.52	0.50
1986	45.0	0.49	0.47	0.43
1987	45.0	0.49	0.27	0.43
1988	42.0	0.71	0.50	0.66
1989	39.0	0.68	0.48	0.63
1990	37.0	0.66	0.47	0.61
1991	34.0	0.40	0.22	0.35
1992	34.0	0.40	0.23	0.35
1993	33.3	0.39	0.22	0.35
1994	33.3	0.39	0.22	0.35

B.4. Germany

There are currently no special tax allowances for R&D. Between 1983 and 1989 industrial buildings and plant and machinery enjoyed limited accelerated depreciation provisions. A building that was at least two-thirds used for R&D purposes could be depreciated at up to 15% of the cost over five years; or 10% if only one-third used for R&D. Plant and machinery used exclusively for R&D, could receive an additional 8% allowance of up to 40% of the initial cost over five years. These accelerated depreciation provisions dramatically reduced the marginal tax wedge on plant and machinery and building R&D expenditure as seen in Table B.4. However, since current R&D accounts for 90% of total R&D expenditure this has not had a large effect on the total R&D tax wedge (see Figure 4 in main body of text). The reduction in the statutory tax rate on retentions from 56% to 45% has reduced the net present value of the deductibility of current expenditure by a far greater amount.

Table B.4. Germany

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	56.0	0.62	0.27	0.54
1980	56.0	0.62	0.27	0.54
1981	56.0	0.62	0.27	0.54
1982	56.0	0.62	0.27	0.54
1983	56.0	0.62	0.44	0.57
1984	56.0	0.62	0.44	0.57
1985	56.0	0.62	0.46	0.57
1986	56.0	0.62	0.46	0.57
1987	56.0	0.62	0.47	0.58
1988	56.0	0.62	0.47	0.58
1989	56.0	0.62	0.47	0.58
1990	50.0	0.57	0.37	0.50
1991	51.9	0.58	0.38	0.52
1992	51.9	0.58	0.38	0.52
1993	50.0	0.57	0.37	0.50
1994	45.0	0.52	0.33	0.46

B.5. Italy

No special tax depreciation provisions or credits are given on R&D expenditure. Italy's statutory tax rate has risen from 36.3% in 1979 to 53.2% in 1994 and thus increased the marginal effective tax wedge on R&D plant and machinery and R&D building expenditure (see Table B.5). However, the immediate expensing of current R&D expenditure (which accounts for 90% of total R&D expenditure) leaves the total marginal tax wedge relatively unaffected (see Figure 4).

Table B.5. Italy

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	36.3	0.36	0.12	0.31
1980	36.3	0.36	0.12	0.31
1981	36.3	0.36	0.12	0.33
1982	38.0	0.38	0.13	0.36
1983	41.3	0.41	0.14	0.41
1984	46.4	0.46	0.17	0.41
1985	46.4	0.46	0.17	0.41
1986	46.4	0.46	0.17	0.41
1987	46.4	0.46	0.18	0.41
1988	46.4	0.46	0.18	0.41
1989	46.4	0.46	0.25	0.41
1990	46.4	0.46	0.25	0.39
1991	47.8	0.48	0.26	0.42
1992	47.8	0.48	0.26	0.42
1993	52.2	0.52	0.30	0.47
1994	53.2	0.53	0.31	0.48

B.6. Japan

Japanese firms can claim a 20% credit on R&D spending exceeding the largest previous annual R&D expenditure. The credit is limited to 10% of tax due before the credit. Buildings and plant and machinery used for R&D activity are also eligible for accelerated depreciation allowances. The statutory tax rate and net present value of this credit is shown in Table B.6. Several additional special credits are also available, although we do not model them here.[21] While the statutory tax rate reported here remains remarkably stable over this period its composition has changed over time. The current statutory tax rate is composed as follows:

[21] These include a 6% credit for small and medium sized firms, a 7% credit for investment to promote basic technology and a 6% credit on R&D carried out in cooperation with government.

Taxable Profits	100.00
Enterprise tax (ET) @12%, base is (100-ET), effective rate is 10.88%	-10.88
Corporate tax base	89.12
Corporate tax @37.5%	-33.42
	55.70
Inhabitants tax @17.3% of corporate tax	-9.64
	46.06

giving an effective statutory rate of 53.94%.

Table B.6. Japan

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	52.7	0.54	0.32	0.47
1980	52.7	0.54	0.32	0.47
1981	52.7	0.54	0.32	0.47
1982	52.7	0.54	0.32	0.47
1983	52.7	0.54	0.32	0.47
1984	52.7	0.54	0.32	0.47
1985	52.7	0.54	0.32	0.47
1986	56.2	0.58	0.34	0.50
1987	56.2	0.57	0.36	0.50
1988	56.2	0.57	0.36	0.50
1989	54.8	0.56	0.34	0.49
1990	52.7	0.54	0.32	0.47
1991	54.8	0.56	0.33	0.48
1992	54.8	0.56	0.33	0.48
1993	54.8	0.56	0.33	0.48
1994	53.9	0.55	0.33	0.48

B.7. The UK

There are no special provisions for R&D except that some capital expenditure on equipment used for R&D in the UK qualifies for a 100% first year allowances under the Scientific Research Allowance. However, a common complaint from industry is that under the current rules a significant fraction of capital expenditure for R&D purposes does not qualify for this allowance. We have therefore not modelled this as universally available. The statutory tax rate and the net present value of the standard depreciation allowances are shown in Table B.7.

Table B.7. United Kingdom

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	52	0.52	0.41	0.52
1980	52	0.52	0.41	0.52
1981	52	0.52	0.41	0.52
1982	52	0.52	0.49	0.52
1983	50	0.50	0.47	0.50
1984	45	0.45	0.42	0.43
1985	40	0.40	0.31	0.36
1986	35	0.35	0.20	0.27
1987	35	0.35	0.15	0.28
1988	35	0.35	0.15	0.28
1989	35	0.35	0.15	0.28
1990	34	0.34	0.14	0.27
1991	33	0.33	0.14	0.26
1992	33	0.33	0.14	0.26
1993	33	0.33	0.18	0.28
1994	33	0.33	0.14	0.26

B.8. The USA

Since 1954 all R&D expenditure has been fully deductible. The Economic Recovery Tax Act of 1981 introduced a tax credit on incremental R&D expenditure which has remained in place, although there have been many subsequent changes to its design, and the credit has never been made a permanent feature of the tax system. The rules governing the operation of the US tax credit are complex and are only sketched out here. A detailed explanation can be found in Hines (1994) and Hall (1995). In particular, we do not consider the foreign allocation rules as we consider only purely domestic firms. The statutory rate of the credit was 25% between 1981 and 1985 and has been 20% since then. From 1981 until 1990 incremental expenditure was defined as spending above the average of the last three years expenditure. In 1990 the definition of the base changed to the three year average ratio of R&D over sales (with a maximum of 16%) times sales. In addition, the rules governing the deductibility of the credit have change. Up until 1988 the credit was not deducted from taxable income. In 1989 it was 50% deductible, and from 1990 onwards 100% deductible. The statutory tax rate and net present value of the tax credit is shown in Table B.8.

Table B.8. USA

Year	Statutory Corporate Tax Rate	NPV Current	NPV Buildings	NPV Plant & Machinery
1979	46	0.53	0.53	0.53
1980	46	0.53	0.53	0.53
1981	46	0.56	0.56	0.56
1982	46	0.56	0.56	0.56
1983	46	0.56	0.56	0.56
1984	46	0.56	0.56	0.56
1985	46	0.56	0.56	0.56
1986	46	0.56	0.56	0.56
1987	34	0.44	0.44	0.44
1988	34	0.44	0.44	0.44
1989	34	0.43	0.43	0.43
1990	34	0.52	0.52	0.52
1991	34	0.52	0.52	0.52
1992	34	0.52	0.52	0.52
1993	35	0.53	0.53	0.53
1994	35	0.53	0.53	0.53