briefing notes

ISSUES IN THE DESIGN AND IMPLEMENTATION OF AN R&D TAX CREDIT FOR UK FIRMS

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1. Introduction

R&D tax credits have become a popular policy tool for encouraging research and development (R&D) spending by business, with many countries offering subsidies of this form.[1] The divergence between private and social rates of return to R&D expenditure by private firms provides one of the main justifications for government subsidies to R&D.[2] In order to achieve the optimal level of R&D investment, government policy aims to bring private incentives in line with the social rate of return. An R&D tax credit does this by reducing the cost to the firm of doing R&D. Recent empirical evidence suggests that R&D tax credits are an effective instrument in stimulating additional R&D. However, in order to be desirable, a policy needs to be cost-effective and implementable.

This Briefing Note reviews some of the major issues in the design and implementation of R&D tax credits. In Section 2, we briefly discuss the existing tax treatment of R&D in the UK. In particular, we outline the new Research and Development Allowance – which is an allowance for expenditure on plant, machinery and buildings for use in scientific research and which is available to firms of all sizes – and the tax credit for R&D that is available to small and medium-sized enterprises (SMEs). We then discuss, in Section 3,

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[1] There are a large range of other policy instruments that could affect the share of GDP that is invested in R&D. Indirect policies such as competition policy and regulation may be important. Direct policies include direct funding of R&D, investment in human capital formation and extending patents protection.

[2] Firms' decisions to undertake R&D are based on their private return to R&D. In general, the literature finds that the social rate of return to R&D is substantially above private rates of return. Because of this, we have underinvestment in R&D. IFS Briefing Note no. 12 (Griffith, 2000) provides a discussion of this literature. The other main justification for government subsidies to R&D is alleviating failings in the financial markets.

some of the main design features of tax credits that have been implemented in other countries. The discussion mainly concerns the question of how to target new or incremental R&D so as to keep down the total exchequer cost. We discuss problems that arise in defining incremental R&D and how these can be tackled. In Section 4, we provide estimates of the amount of new R&D and the exchequer cost that would be likely to result from implementing different designs of R&D tax credit in the UK. Section 5 concludes. Some technical details are dealt with in the Appendix.

2. The current tax treatment of R&D in the UK

The UK tax system gives special treatment to R&D in SMEs and to capital expenditure for R&D in all firms. The Research and Development Allowance[3] (R&DA) allows plant, machinery and buildings to be immediately written off against profits. This treatment is more generous than that for similar expenditure for non-R&D activity, where there is a 4 per cent depreciation allowance for buildings and a 25 per cent depreciation allowance for plant and machinery. However, since R&D is made up of around 40 per cent wages and salaries, 50 per cent current expenditure and 10 per cent capital expenditure, it does not provide a very significant subsidy to overall R&D.[4] Wages and salaries and current expenditure on R&D receive no special tax treatment. As with all current expenditure and wages and salaries, these expenditures can be immediately written off against profits.

In the Finance Bill 2000, the government introduced an R&D tax credit aimed at SMEs.[5] There are two parts to the scheme. The first is called R&D tax relief and allows eligible companies to deduct 150 per cent of qualifying R&D from their taxable profits. The second part is a repayable tax credit and is aimed at companies that are not in profit. The company can surrender its qualifying R&D losses to the exchequer in exchange for a cash payment worth 24 per cent of the spending on R&D. The R&D expenditure must be at

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[3] This used to be called Scientific Research Allowance and did not include development prior to April 2000.
[4] See Office for National Statistics (2000).
[5] The legislation is found in Section 69 and Schedules 19 and 20, and applies to qualifying R&D expenditure incurred on or after 1 April 2000. See http://www.inlandrevenue.gov.uk/r&d/index.htm for details.

least £25,000 a year and the project cannot have received any other government funding, such as Smart or Link. The R&D can be carried out either in the UK or overseas. An additional restriction is that a claim for the payable R&D tax credit cannot exceed the PAYE / National Insurance liabilities of the company for that accounting period.

An SME is defined as a firm that has fewer than 250 employees and either an annual turnover not exceeding 40 million Euros (about £25 million) or an annual balance sheet total not exceeding 27 million Euros (about £17 million). Any company in which the SME holds 25 per cent or more of the capital or voting rights must be included in this calculation.

3. Issues in designing a broader tax credit

In the November 1998 Pre-Budget Report,[6] the government floated the idea of introducing a tax credit that would be available to a wider range of firms, rather than only to SMEs. In considering the introduction of such a tax credit, there are several design features that the government will have to consider. One big choice is whether to subsidise all R&D (a volume-based credit) or just the additional amount of R&D expenditure over some base (an incremental credit). In this section, we explain the difference and discuss problems that arise in defining incremental R&D. In particular, we consider systems that are in use in other countries, which include the use of a rolling-average base or a fixed base.

A useful measure of the incentives a tax credit provides is the marginal effective tax credit (METC). The METC measures the impact of the tax credit on the price for the firm of increasing R&D expenditure by £1. This may differ from the headline credit rate for a number of reasons, which we explain below. We use a headline credit rate of 20 per cent for illustrative purposes.

3.1 Volume versus incremental tax

The aim of an R&D tax credit is to reduce the cost to firms of undertaking R&D. A volume-based credit gives firms a subsidy on every £1 of R&D they undertake. The

METC in that case is always identical to the credit rate. With a credit of 20 per cent, spending an extra £1 on R&D will always increase the credit received by 20p.

A disadvantage of volume-based credits is that they not only subsidise new R&D but also subsidise the R&D a firm would have done anyway. This means that part of the expense the government incurs does not have any impact on firms' incentives to do more R&D (it leads to a large dead-weight cost). This is the reason that many governments have tried to target incremental R&D expenditure. This means that the tax credit only gives firms a subsidy on additional R&D expenditure (marginal R&D), not on the R&D they are already doing (non-marginal R&D). If this can be done effectively, then it increases firms' incentives to do R&D in the same way as a volume-based credit, but at a much lower exchequer cost.

Consider as an example a firm that did £100 of R&D last year and £120 this year. A volume-based credit at the assumed rate of 20 per cent would give the firm 20% × £120 = £24. An incremental credit would give the firm 20 per cent of the incremental or marginal R&D that it had done – in this case, 20% × (£120 – £100) = £4. The impact on the firm's incentives to invest more will be the same under each scheme: when the firm is considering the cost of spending an extra £1 on R&D, it knows that it will receive £0.20 for each additional £1. However, the exchequer cost of the volume-based tax credit is far greater than that of the incremental one.[7]

The main problem in designing an incremental tax credit is the difficulty of defining incremental R&D. To reach a definition of incremental R&D, a base level of R&D needs to be defined for each firm. Incremental R&D is then defined as R&D above this base level. Two methods that are used in other countries are (i) to define the base as a rolling average of some number of past years' R&D (e.g. the past year, as in the example above, or the past two or three years) or (ii) to define the base with reference to a fixed year. In addition, the base can be defined as an absolute amount of R&D or as a ratio of R&D to

[6] HM Treasury, 1998.
[7] If, instead, we think of the government setting aside a fixed amount of cash for R&D tax credits, then an incremental credit could offer a much higher credit rate than a volume-based credit.

sales (or some other measure of firm size). Each of these systems is defined, and their relative merits are discussed, below.

3.2 Rolling-average-base R&D tax credits

A rolling-average-base design was used in the US until the Omnibus Budget Reconciliation Act of 1989 and is currently used in the French and Canadian tax credit systems. A base level of R&D is defined as the average firm-level expenditure on R&D over the preceding years. The number of years over which the base is defined varies from country to country. A firm's incremental or marginal R&D is then defined as the difference between its current R&D expenditure and this base.

This system can lead to reduced, and sometimes perversely negative, R&D incentives.[8] In a dynamic setting, firms will take into account the effect that increasing their current R&D expenditure will have on the future definition of their incremental base. The simplest case of an incremental base is where the R&D base level is equal to the previous year's expenditure on R&D. A firm operating in such a setting knows that increasing R&D by £1 this year will lead to a direct payment of 20p. But this additional £1 will also increase the base level of R&D in the following year. Incremental R&D expenditure will thus be reduced by £1 in the next year (provided the firm's R&D is not declining).

What does this do to the value of the credit? First note that £1 tomorrow is not worth as much as £1 today – firms discount future earnings. We assume a discount rate of 10 per cent, which means that £1 tomorrow is worth 91p today. The total effect of spending an extra £1 on R&D is a positive revenue of 20p less a discounted loss of revenue in the following year. The METC will thus be

0.20	$-\frac{1}{1+0.1}\times 0.20$	$= 0.018$
20p this year	*minus* discount rate *times* 20p next year	= METC

[8] See Eisner, Albert and Sullivan (1984) for an early discussion of these issues in the US context.

Thus a statutory credit rate of 20 per cent turns into an METC of 1.8 per cent. Similarly, the METCs for two- and three-year rolling-average bases can be calculated as 2.6 per cent and 3.4 per cent (for formulae and calculations, see the Appendix). There is also a difference in the payment a firm receives under each of these definitions of base. Consider a firm that increases R&D by £10 every year. This firm receives a payment from the credit in each year since its current expenditure is always above its base level. When the base is defined as last year's expenditure, the payment is always £2 a year (20 per cent of the £10 increase over last year's R&D expenditure); when the base is average expenditure over the past two years, the payment is £3 a year; and for a three-year rolling-average base, it is £4 a year.[9] For firms in this position, the payment is higher the longer the time period used to define the base because some non-marginal R&D is being subsidised.

These METCs are calculated under the assumption that R&D expenditure does not decline. If it does, then negative METCs can occur. A firm whose R&D expenditure is more than £1 below the base level will not be paid any credit if it increases its expenditure by £1. The direct revenue effect of the increase would be zero. But, if the firm expects to increase R&D in future years, then increasing expenditure now will increase its future base and thus lead to a loss of revenue in the future. In our example above, where the base is defined as last year's R&D level, the total effect of increasing expenditure by £1 will be a revenue of 0p this year and a loss of 20p (20 per cent of £1) next year. The METC is the present discounted value of this calculation:

0.0	$-\frac{1}{1+0.1}\times 0.20$	= –0.1818
0p this year	*minus* discount rate *times* 20p next year	= METC

[9] Taking a firm that increases it R&D expenditure by £10 every year, its current expenditure will be £15 and £20 above its two-year and three-year rolling-average bases respectively. Applying a 20 per cent credit to these figures leads to these £3 and £4 credit payments.

i.e. the METC will be –18.18 per cent. Because of these effects, rolling-average-base credits can lead to fluctuations in the value of the tax credit if R&D does not follow a smooth growth path.

Table 1 illustrates the case of a firm whose R&D expenditure does not increase each year. R&D spending by the firm increases smoothly in most years, but there is zero R&D in one year (year 4) and correspondingly more R&D in the following year (year 5). This simple shifting of R&D expenditure from one year to the next greatly affects both the tax credit payments and the METC.

Table 1: Payment and METC for firms with at least one year's negative R&D growth

Year	R&D spending	Payment			METC		
Definition of base:		1-year	2-year	3-year	1-year	2-year	3-year
1	55	2	3	4	0.018	0.026	0.034
2	65	2	3	4	0.018	0.026	0.034
3	75	2	3	4	0.200	0.117	0.034
4	0	0	0	0	-0.182	-0.174	-0.166
5	180	36	28	27	0.200	0.109	0.084
6	105	0	3	4	-0.182	0.117	0.089
7	115	2	0	4	0.018	-0.174	0.095
8	125	2	3	0	0.018	0.026	0.034
9	135	2	3	4	0.018	0.026	0.034
10	145	2	3	4	0.018	0.026	0.034

Note: We have assumed the firm also increases its level of R&D expenditure by £10 a year before year 1 and after year 10.

We see that, in year 4, when the firm cuts back its level of R&D expenditure to below its base, it receives no tax credit payments and has a negative METC. In reverse, in year 5, when the firm increases its level of R&D expenditure, it has large positive credit payments and a large METC rate. Hence these rolling-base credit systems can create pro-cyclical incentives, with large positive credits in R&D booms and negative credits in R&D busts. In Table 1, it can also be seen that the volatility of incentives is largest for the one-year rolling base and least for the three-year rolling base. This is because longer rolling-average bases tend to reduce the effect of R&D shocks in any single year by spreading them out over more years.

A variant of this type of system is to use the maximum R&D expenditure over the previous years as a definition of the base, rather than the average. This has been the procedure in Japan since 1967. With the maximum defined over the infinite past and for firms whose R&D never declines, the METC will be the same as for the one-year rolling base. The advantage of this definition of the base is that it will never yield a negative METC.[10]

3.3 Fixed-base R&D tax credits

In order to target incremental R&D while avoiding the negative dynamic effects of using a rolling base, some countries, such as the US, have fixed the definition of base R&D. This still leaves the question of choosing the appropriate R&D base. Two potential schemes are discussed here – an inflation-indexed fixed base and a sales-indexed fixed base (as currently used in the US). These systems both have the advantage that the METC is never negative, and for firms whose R&D does not fall below the base, the METC is equal to the full credit rate.

Inflation-indexed fixed R&D base

Under the inflation-indexed fixed-base system, the base is defined as the level of R&D undertaken in a specific year. This amount is then updated each year by inflation. R&D over and above this base is defined as incremental R&D and is eligible for the tax credit. This means that for firms whose real R&D is growing, the METC will always be equal to the full credit rate. For firms that experience a decline in R&D expenditure, which happens in about a third of quoted UK firms,[11] R&D expenditure will be below their base. The METC rate will then be zero. The R&D credit will have no impact on such firms until their R&D grows above their base level again.

One modification of this system is to update the fixed base – for example, by resetting the indexed base every five years. However, this would again lead to problems of negative dynamic incentives. As long as the R&D growth rate is similar to the rate of inflation,

[10] This does not hold, however, if the maximum is defined over a fixed number of years instead of the all-time maximum expenditure. In this case, negative METC can result.
[11] In the sample of UK firms we used to evaluate the R&D tax credit in Section 4, falling real R&D expenditure occurred in 41 per cent of observations.

this modified system is quite effective; however, if they get out of line, the effectiveness of this system declines. An attempt to tackle this problem is to use sales instead of inflation to index R&D (the idea being that sales at the firm level may track R&D better than inflation does).

Sales-indexed fixed R&D base

An alternative definition of the R&D base is to index the level of R&D by the firm's sales. This is the system currently in place in the US. The effect of this is that a firm can claim a tax credit whenever its R&D expenditure constitutes a higher percentage of sales than in the year the base was fixed. For firms that keep their R&D/sales ratio above that in their base year, the METC will always be the full credit rate. One problem with this approach is that the base will expand and contract in line with total sales, which may be more volatile than R&D expenditure.

The efficiency of this system depends on the extent to which the R&D/sales intensity remains constant over time. The tax credits will be too generous for firms whose R&D/sales intensity rises for reasons that are independent of the credit. Some of the credits will then be paid for non-incremental R&D. For firms whose R&D/sales intensity falls (so that the base is too high), marginal R&D will not be eligible for any tax credits.

We find that, in general, the reduction in efficiency and the dispersion of incentives over time are likely to be less important using a sales-indexed base than using an inflation-indexed base, as a firm's actual R&D level is more strongly correlated with an index updated by sales than by inflation (see Table 2 later). The improved targeting of marginal R&D using the sales-indexed R&D base leads to a higher ratio of new R&D to revenue cost than for the inflation-indexed fixed base.[12]

Another consideration when using fixed-base credits is the choice of the base year. In any given year, some firms will happen to be spending more on R&D during the year than their long-term average – for example, to develop a promising new innovation. Other firms may have spent less than they normally do, possibly in response to short-term

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[12] Although this may hold in general, for some firms, using a sales-indexed base will be problematic, e.g. if firms undergo major corporate restructuring.

financing problems. Therefore, picking a specific year from which to use the R&D/sales ratio to index the future base may be inappropriate. Instead, a more suitable base could be created by taking an average of, for example, the three most recent year's R&D/sales ratios. A three-year average trades off the advantages of taking longer averages to smooth out year-to-year fluctuations in firms' R&D/sales ratios against using more recent information.

4. Illustrations of new R&D and exchequer cost

The discussion above highlighted several issues in designing an R&D tax credit. Recent empirical work has suggested that R&D tax credits are an effective means of stimulating new R&D.[13] However, the question still remains of whether they are desirable – are they cost-effective? In Table 2, we present estimates of new R&D stimulated by the credit and the total exchequer costs of four hypothetical R&D tax credit schemes. We calculate these using a sample of 138 UK firms and assuming a price elasticity of –1.0 (this means that, for each additional subsidy of 20p, the firm will spend an extra 20p on R&D). The average marginal effective tax credit (METC), which represents the actual 'strength' of these tax credits, is also reported for each scheme. They are calculated as discussed in the previous section and in the Appendix. Each column of the table represents a different design of tax credit. All four use a headline rate of 20 per cent. The first column models a volume-based credit, the second an incremental credit using a three-year rolling-average base and the third an inflation-indexed fixed-base credit, while the fourth column illustrates a sales-indexed fixed-base credit.

[13] See, for example, Hall and Van Reenen (1999) and Bloom, Griffith and Van Reenen (2000).

Table 2: An illustration of new R&D and exchequer costs for four tax credits

	Volume credit (no base)	Three-year rolling-average base	Inflation-indexed base	Sales-indexed base
Average METC	20%	3.5%	14.6%	14.7%
(Min, Max) METC	(20%, 20%)	(–16.6%, 20%)	(0, 20%)	(0, 20%)
Correlation, R&D and R&D base	n.a.	0.96	0.89	0.95
Revenue cost	£820.8m	£126m	£199.2m	£145.2m
New R&D in first year	£68m	£11m	£50m	£43m
Long-run new R&D	£684m	£113m	£497m	£427m
Long-run new R&D / revenue cost	0.83	0.90	2.48	2.94

Notes: The figures are calculated for our sample of 138 quoted firms in 1994 only, and so do not represent the whole population of UK firms. The headline credit rate is 20 per cent. The own-price elasticity is –0.1 in the short run and –1.0 in the long run.

Guide to Table 2:

Average METC: The average marginal effective tax credit is the weighted average of the METC for 138 individual firms. The weights are R&D expenditure. The unweighted figures look very similar.

(Min, Max) METC: This displays the lowest and highest marginal effective tax credit experienced by any firm in our sample in 1994. It gives an indication of the distribution of the incentives provided across firms.

Correlation, R&D and R&D base: This reports the correlation of the firm's level of R&D with its R&D base, which indicates how closely the R&D base matches the firm's marginal R&D – higher correlations denote a closer match.

Revenue cost: This presents an estimate of the revenue cost to the exchequer based on our sample of 138 firms (so does not represent an actual estimate of total exchequer cost). It is used in the last row to compare new R&D with cost.

New R&D in first year: This presents an estimate of the additional R&D generated in the first year by the tax credit. It uses the short-run (first-year) tax price elasticity of R&D of –0.1, as estimated by Bloom, Griffith and Van Reenen (2000). This would rise over time to the longer-run estimate of new R&D.

Long-run new R&D: This presents an estimate of the additional R&D generated by the tax credit. It uses the long-run tax price elasticity of R&D of –1.0, as estimated by Bloom, Griffith and Van Reenen (2000).

Long-run new R&D / revenue cost: This presents an estimate of the ratio of additional R&D to revenue costs in the long run.

From Table 2, it is clear how critical the design choice of an R&D tax credit is. In particular:

- Targeting all R&D through a volume credit provides a generous credit but at a high revenue cost. Overall, the effectiveness of this volume credit, in terms of new R&D / revenue cost, is about the same as that of the rolling-average-base credit but lower than that of either of the fixed-index-base credits.
- Introducing a rolling-average base is cheap but not very effective in stimulating new R&D. This system creates a high degree of inequality in the METC rate faced by individual firms. In our sample of 138 firms, 20 per cent faced a negative METC. The one-, two- and three-year-base systems all provide about the same amount of new R&D per revenue cost. This equivalence arises because, while the three-year base has a higher METC, it also subsidises more non-marginal R&D because its base tracks the firm's actual R&D expenditure less closely. These two effects cancel out.
- Creating a fixed base provides a more effective trade-off. However, over time, the base will become more out of line with actual firm behaviour, so that this cost advantage slowly diminishes. Periodic rebasing is one option, though that can potentially lead to problems with firms' dynamic incentives in a similar way to the rolling-average base. Because sales indexation is more effective at matching the R&D base than inflation indexation, it provides a greater new R&D / revenue cost trade-off.

It should also be noted that these credits will provide the bulk of their assistance to large firms. If an R&D tax credit is introduced to bring the private returns to R&D up to the social returns, then there does not appear to be any particular reason why this should be a problem.[14] When spillovers affect large firms and small firms equally, the distribution of an appropriately targeted R&D tax credit will mimic the distribution of R&D across firms. R&D in the UK is concentrated in a small number of firms, and thus the provision of the R&D tax credit will also be concentrated.

It is also the case that R&D expenditure (as defined by tax laws and accounting standards) is predominantly concentrated in the manufacturing sector, which accounts for about 80 per cent of R&D but only 20 per cent of employment and value added.[15] An R&D tax credit will therefore provide a strong fiscal incentive to the UK manufacturing sector.

5. Conclusion

This note has not addressed the question of whether an R&D tax credit should be introduced. Instead, it has analysed the issues that arise in designing such a tax credit if one is to be introduced. It was noted that volume-based tax credits are comparatively expensive. Incremental tax credits can be better value for money, provided the base is defined so as to avoid disincentive effects. There are, however, big problems in defining incremental R&D in a way that does not provide firms with perverse incentives. These can be overcome by using fixed-base systems or by using a firm's all-time maximum expenditure as a base.

There are many other issues that would need to be addressed in the implementation of a tax credit that have not been discussed here. These include legal issues about compatibility with the rest of tax law, considerations about compliance costs, whether to restrict the tax credit to R&D performed in the UK, whether to make the credit repayable to tax-exhausted firms and whether to consider all current R&D expenditure or just some components, such as wages.

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[14] See, for example, Griffith (2000).

[15] See the OECD's *Analysis of Business Expenditure on R&D* (ANBERD) (1999) and *International Sectoral Database* (ISDB) (1997) publications.

Appendix

Calculating the revenue costs and additional R&D for tax credit systems

The sample of firms

The estimates in Table 2 are made on a sample of UK quoted firms extracted from the UK Datastream on-line service. In order to use a comparable set of firms, the criteria for selection required that each firm:

- has continuously reported R&D expenditure over 1991–97 inclusive: the data for 1991–93 enable a three-year rolling-average base to be calculated for 1994; the data for 1995–97 enable the effects of 1994's R&D expenditure on the firm's future rolling-average bases to be calculated.
- is not involved in any major merger or break-up. Such a move would lead to a jump change in the R&D base and invalidate our simple fixed-base system. This criterion excludes, for example, Glaxo Wellcome and Zeneca, as they were involved in a major merger in 1995 and a break-up in 1992 respectively. To include these firms in our study, we would need to append our fixed-base rules to deal with mergers, acquisitions and start-ups.

This gives us a sample of 138 quoted firms on which we base our calculations. They are large firms which had average yearly sales of £1.7 billion and yearly R&D expenditures of £26 million.

Methodology for calculations in Table 2

For all systems, we assume that firms are paying enough tax to ignore the effects of tax exhaustion on the credit value. The R&D data are based on UK accounting data and so our figures may include R&D undertaken by overseas subsidiaries, which we model as being eligible for the tax credit, but exclude R&D undertaken by foreign multinationals in the UK.

For calculating the effects of the rolling-base credit, we assume that firms can predict whether future R&D expenditures will be above or below their rolling-average bases. We also assume that firms use a 10 per cent rate to discount future revenue streams.

For calculating the effects of a fixed-base system, we assume the base index was set in 1991, which ensures comparability of our data sample across the columns of Table 2.

The effective value of a rolling-base tax credit

The marginal effective tax credit (METC) is the credit rate that a firm experiences on the marginal £1 of R&D. The METC will be affected by

- the credit rate;
- the firm's discount rate;
- levels of past and current R&D expenditure and the expected future growth path of R&D expenditure (the key issue being whether R&D expenditure is above the base).

For a credit given at rate c and for a discount rate of r, the METC for a k-year rolling-average base is given by

$$METC_t = c\left[D_t - \frac{1}{k}\sum_{i=1}^{k}(1+r)^{-i} D_{t+i}\right]$$

where

$D_t =$	0	if R&D is below base in year t
	1	if R&D is above base in year t

So, for a credit of 20 per cent and assuming a discount rate of 10 per cent, the METCs for a firm whose R&D never declines are

METC, one-year rolling-average base

$$= 0.20 - \frac{0.20}{(1+0.10)} = 0.018;$$

METC, two-year rolling-average base

$$= 0.20 - \left(\frac{1}{2}\right)\frac{0.20}{(1+0.1)} - \left(\frac{1}{2}\right)\frac{0.20}{(1+0.1)^2} = 0.026;$$

METC, three-year rolling-average base

$$= 0.20 - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)} - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)^2} - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)^3} = 0.034.$$

If we instead assume that R&D is below the base in the current year, but will be above base in future years, the METCs become

METC, one-year rolling-average base

$$= 0 - \frac{0.20}{(1+0.10)} = -0.1818;$$

METC, two-year rolling-average base

$$= 0 - \left(\frac{1}{2}\right)\frac{0.20}{(1+0.1)} - \left(\frac{1}{2}\right)\frac{0.20}{(1+0.1)^2} = -0.1736;$$

METC, three-year rolling-average base

$$= 0 - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)} - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)^2} - \left(\frac{1}{3}\right)\frac{0.20}{(1+0.1)^3} = -0.1658.$$

If we assume that R&D is above the base now, but will be below the base in all future years, then the METC will be the full 20 per cent in all three cases.

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