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An Evaluation of the Federal Tax Credit for Scientific Research and Experimental Development

by

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Abstract

Canada has one of the world's most generous tax regimes for private research and development (R&D), with a federal tax credit of 20% to 35% on a broad range of eligible spending. This paper evaluates the federal scientific research and experimental development tax credit, taking into consideration the responsiveness of the private sector to changes in the price of R&D, the spillovers on the rest of the economy from the additional R&D, the economic cost of raising taxes to fund the credit and the administration and compliance costs associated with the credit.

The key parameters used in the evaluation were determined after an extensive review of the recent empirical literature. Based on this review, the study concludes that the SR&ED tax credit generates a net economic gain for Canada.

JEL classification: H23, H2; O3.

Résumé

Le régime fiscal canadien est l’un des plus généreux au monde pour la recherche et le développement (R-D) dans le secteur privé, avec un crédit d’impôt fédéral de 20 % à 35 % accordé sur un vaste éventail de dépenses admissibles. Le présent document évalue le crédit d’impôt fédéral pour la recherche scientifique et le développement expérimental, en tenant compte de l’adaptation du secteur privé à l’évolution du coût de la R-D, des retombées de la R-D additionnelle sur le reste de l’économie, du coût économique de la perception de taxes pour financer le crédit et des coûts d’administration et d’observation liés au crédit.

Les principaux paramètres utilisés dans le cadre de l’évaluation ont été déterminés après un examen exhaustif de récents documents de recherche empirique. Suivant cet examen, le crédit d’impôt pour la RS et le DE entraîne un gain économique net pour le Canada.

Classification JEL : H23, H25; O3.

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1. Introduction

The federal government supports investments in research and development (R&D) through both the tax system and spending programs. The most significant tax incentive is the federal Scientific Research and Experimental Development (SR&ED) tax credit, which cost approximately $2.8 billion in 2004.[1] In addition to the credit, the federal government directly funds a considerable amount of R&D, totalling $4.7 billion in 2004.[2]

Underpinning Canada's generous tax subsidies for R&D is the widely accepted view that private research provides substantial social benefits. R&D tax incentives help correct the failure of the market to provide a socially desirable amount of R&D capital by compensating firms for the spillover benefit their research provides to others. These incentives may also help alleviate financing constraints on R&D investment, particularly those faced by smaller firms.

A major review of the SR&ED tax credit was published in 1997 by Finance Canada and Revenue Canada. Using survey data, it finds that the federal SR&ED credit generates $1.38 in incremental R&D spending per dollar of foregone tax revenue. The evaluation also employs a general equilibrium model to show that, given very conservative external return estimates, the Canadian economy is better off providing incentives for R&D.

This study provides an update of the 1997 SR&ED evaluation.[3] Using results from the recent empirical literature on R&D, a partial equilibrium model is developed that considers not only the additional R&D induced by the tax credit, as described by the incrementality ratio, but also the additional benefits brought by R&D spillovers and the

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[1] This is taken from Finance Canada (2006) which reports the tax expenditures on a cash flow basis, in whereas this evaluation uses an accrual basis (see Section 3.4 and Annex 1).

[2] Nearly half of this amount (48.5 percent) represents grants to universities, 45.1 percent undertaken by the federal government itself, and 6.1 percent represents grants to business. Source: Statistics Canada, CANSIM Table 358-0001.

[3] Annex 4 compares models and parameter assumptions used in other evaluations. For example, compared to the 1997 evaluation, we include administrative and compliance costs, and, consistent with recent literature, apply a lower incrementality ratio, a higher external return to R&D and a higher marginal excess burden of taxation.

additional costs associated with raising distortionary taxes to finance the credit as well as administration and compliance costs. Given the central values of these factors, the model indicates that the SR&ED credit results in a net welfare gain. The tractable decomposition of the welfare effects is the principal advantage of our partial equilibrium framework, which is enhanced through the use of recent estimates from the literature.[4]

2. Review of Empirical Literature

If the market allocates resources efficiently, subsidies on specific inputs or assets lead to an inefficient allocation of resources and a reduction in aggregate output.[5] Targeted subsidies can only be justified on efficiency grounds in the presence of a "market failure". R&D is one input that receives special tax treatment worldwide mainly on the grounds that it generates significant externalities in the form of knowledge spillovers. Subsidizing this factor of production is generally believed to help correct this market failure, bringing R&D investment closer to socially desirable levels.

The existence of a spillover effect is not sufficient to justify a subsidy, such as an R&D tax credit. Not only must private R&D investment be responsive to the subsidy, but the spillovers must also be large enough to offset the costs of the subsidy. First, raising taxes to finance an R&D tax incentive creates a welfare cost by distorting economic behaviour, such as by reducing the incentives to save, work and invest. Second, government resources must be devoted to administering the subsidy and private resources must be devoted to complying with the provisions of the credit. Whether a tax credit for R&D is on balance beneficial, therefore, rests largely on the magnitude of the spillovers relative to the associated costs. Dahlby's (2005) framework for evaluating provincial R&D tax incentives incorporates the cost of raising taxes, the spillovers from

[4] Our model is partial equilibrium in the sense that it treats many endogenous variables (e.g. cost of R&D, returns to R&D) as exogenous and excludes some potential channels of influence, such as payments to foreign factors and terms of trade effects (See section 5.1). A key parameter in our model, the marginal excess burden of taxation, is taken from a Canadian general equilibrium model by Baylor & Beauséjour (2004).

[5] This is a well-know result of the Production-Efficiency Theorem by Diamond & Mirrlees (1971).

R&D and the sensitivity of R&D spending to tax incentives.[6] Before applying our own framework to the evaluation of the federal SR&ED tax credit, we review in this section the literature on our key evaluation variables: the responsiveness of R&D to tax incentives, the spillover benefits that flow from R&D, the costs of raising distortionary taxes, and administration and compliance costs.

2.1 Sensitivity of R&D Investment to Tax Incentives

To evaluate the SR&ED program, it is necessary to have an understanding of the sensitivity of private R&D spending to tax incentives. There are two closely related measures of responsiveness: R&D price elasticity and the incrementality ratio. The R&D price elasticity measures the percentage change in R&D spending by the private sector for every percentage change in the user cost of R&D. The incrementality ratio measures the change in R&D spending per dollar of tax revenue foregone by the government due to the tax incentives. It is more commonly known as the cost effectiveness ratio, but we prefer not to use this term since it implies a full cost benefit analysis whereas the measure omits important costs and benefits such as distortionary taxes and spillovers.[7] In this section, we review recent studies that estimate both measures. We also propose a standard method for converting long-run price elasticity estimates into incrementality ratios.

The response of R&D spending to tax incentives can be estimated using either a survey approach or by conducting econometric analysis. Under the survey approach, firms are typically asked to estimate the impact of the tax incentives on their R&D expenditures. The survey sponsored by Finance Canada and Revenue Canada (1997) asked 501 Canadian firms how much lower or higher their R&D would be in the absence of SR&ED tax incentives. Weighting the responses by the R&D expenditures of each

[6] Dahlby (2005) assumes that spillovers captured provincially are substantially less than overall domestic spillovers, in which case they are not likely high enough to warrant adopting a provincial R&D subsidy in Alberta. Prince Edward Island and Alberta are the only provinces without a provincial incentive for R&D. See McKenzie (2005) for a review of provincial tax incentives for R&D.
[7] Unlike a true cost benefit ratio, an incrementality ratio that is greater than one is not sufficient to conclude that the program is worthwhile.

firm, the study found that the SR&ED program lifted R&D spending by 32 percent overall and by $1.38 per dollar of tax expenditure on the program. Other R&D surveys have yielded lower levels of incrementality, including Mansfield and Switzer (1985a and 1985b) for Canada, Mansfield (1985 and 1986) for Sweden and Mansfield (1986) for the U.S. Although the survey approach provides the researcher with a high level of information, there is a possibility that respondents may exaggerate the benefits of policies that advantage them.

Econometric analysis is the most common way to estimate the responsiveness of R&D to tax incentives. Under this approach, the researcher attempts to explain R&D investment using a set of variables, which may include firm size, profitability, cash flow, industry type, and tax variables. The non-tax variables help control for changes in R&D that result from structural characteristics of the firm or industry, enabling the researcher to isolate the marginal impact of changes in the tax parameters on R&D spending. For example, some studies such as (Hall and Van Reenen, 2000) estimate the price elasticity of R&D with respect to the tax credit by regressing the change in business R&D on changes in the user cost of R&D (both in logs) and control variables. The coefficient on the user cost measures the R&D price elasticity, which can be used to calculate the incrementality ratio of R&D.

One of the more recent cross-country econometric studies to estimate the responsiveness of R&D tax credits was conducted by Bloom, Griffith and Van Reenen (2002) using data from 1979 to 1997 for a sample of OECD countries. The authors develop an R&D user cost measure, which incorporates estimates of the real interest rate, depreciation rates and the tax credit. They then estimate a model with private R&D as the dependent variable and user cost, output and fixed (time and country) effects as the explanatory variables. Using an instrumental variables approach to account for the endogeneity of the user cost, Bloom et al. find that tax credits have a significant effect on the level of private R&D, reporting an elasticity of –0.1 in the short run and –1 in the long run. McKenzie and Sershun (2005) also use a sample of OECD countries over the same period, but estimate a slightly smaller R&D price elasticity of between –0.7 and –0.9 in the long run.[8]

Many of the R&D price elasticity and incrementality estimates are based on U.S. data. Hall (1993) examines the evolution of private sector responses to the incremental research and exploration (R&E) tax credit that was introduced by the U.S. federal government in 1981 as part of the Economic Recovery Act.[9] Using a panel of U.S. firms during the 1980s, she finds an absolute elasticity of just under one in the short run and over two in the long run. By separating the regressions into 1980-85 and 1981-91 periods, Hall discovers that the absolute price elasticity increases in the latter period, suggesting that it took firms time to react to the presence of the credit, consistent with Bloom, Griffith and Van Reenen (2002). Based on these results, Hall calculates that the credit stimulated $2.00 of R&D spending per dollar of revenue foregone (i.e. an incrementality ratio of 2). Using U.S. firm level panel data in the late 1980s, Berger (1993) estimates that R&D tax incentives induced $1.25 of R&D investment per dollar of subsidy. Hines (1993) looks at the R&D spending of U.S. multinationals surrounding significant tax changes introduced in 1986. He calculates that these tax changes, which reduced the amount of R&D expenses some U.S. multinationals could deduct against U.S. income, induced a negative R&D response of between $1.2 and $1.8 per dollar of revenue raised. Other studies using U.S. data find lower tax sensitivity estimates. For example, Tillinger (1991), using U.S. firm level data between 1980 and 1985, estimates that tax incentives raised R&D spending by only $0.19 per dollar foregone. McCutchen (1993) finds a slightly higher, but still low, impact of between $0.29 and $0.35 per dollar of subsidy.

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[8] A major difference in the McKenzie and Sershun paper relative to other papers in the literature is that they estimate the impact of the marginal cost of subsequent production (the "pull" effect) on R&D spending in addition to the conventional user cost effect (the "push" effect). The elasticity of –0.7 to –0.9 reported above relates to the user cost effect.

[9] In contrast to the Canadian SR&ED tax credit, which subsidizes all R&D spending, the U.S. R&D tax credit subsidizes only additional R&D spending relative to a baseline average. Elasticities are comparable between countries with incremental or level subsidies, however the impact of the subsidies on the user cost is different.

Summarizing the R&D fiscal incentive literature in the U.S., Hall and Van Reenen (2000) conclude that "the R&D tax credit produces a roughly dollar-for-dollar increase in reported R&D spending on the margin" (p. 462). They suggest studies using older data found a lower tax response because, when they were carried out, tax credits were new and firms had not fully reacted to their presence.

Table 1 provides price elasticity and incrementality ratio estimates that have been published since 1990 for Canada and other countries, while Annex 2 provides a more detailed review. In choosing a parameter value for our model, we rely on Canadian data to find evidence of the effect of tax on R&D. Long run estimates are preferred, since Canada's SR&ED tax credit has existed in various forms since the 1980s and we are interested in its long run consequences.[10] Dagenais, Mohnen and Therrien (1997) estimate a long-run R&D price elasticity of –1.09 using a sample of Canadian firms between 1975 and 1992. Based on these results, they calculate that tax incentives increase the long-run level of R&D stock by $0.98 per dollar of revenue foregone in present value terms. Lebeau (1996) estimates an incrementality of $0.9 using industry data for the province of Quebec.

The incrementality ratio is directly estimated in two of the Canadian studies. Finance Canada and Revenue Canada (1997) find an incrementality ratio of 1.38 using a survey approach. Klassen, Pitman and Reed (2004), in an econometric study of 58 Canadian firms between 1991 and 1997, estimate that, on the margin, one dollar of tax incentives stimulates $1.3 in R&D.[11] Their methodology is unusual in that it estimates incrementality directly by regressing the log of R&D on the credit rate. In the other studies, the incrementality ratio is either not calculated directly or is calculated using a variety of methodologies.[12]

[10] Guellec et al (2003) find that expectations that an R&D incentive is permanent, as measured by its stability over time, strengthen its incentive effect. This bolsters the case for using long term estimates, which tend to be larger.

[11] Although this is a recent estimate, we do not wish to place undo weight on a single estimate, so we rely on the medium of empirical estimates.

[12] For example, Dagenais, Mohnen & Therrien (1997) calculate the present value of additional R&D per additional dollar of R&D expenditure as R&D moves towards its higher optimal capital stock. Nadiri &

To improve comparability across studies, we introduce the following method for converting an R&D price elasticity into an incrementality ratio (*I*):

$$I = \frac{\Delta RD}{\Delta TE} = \frac{RD_1 - RD_0}{RD_1 \phi} \tag{1}$$

where ϕ is the effective credit rate, RD_0 is R&D investment without the credit, RD_1 is R&D investment with the credit, and *TE* is the tax expenditure associated with the SR&ED tax credit (we use 'tax expenditure' and 'tax subsidy' interchangeably).

Since $RD_1 = RD_0(1 - \varepsilon\phi)$, where $\varepsilon < 0$ denotes the elasticity of R&D investment with respect to the user cost, we can write equation (1) as:

$$I = \frac{RD_1\left(1 - \frac{1}{1 - \varepsilon\phi}\right)}{RD_1 \phi}$$

which can be simplified to:

$$I = \frac{-\varepsilon}{1 - \varepsilon\phi} \tag{2}$$

According to equation (2), the incrementality ratio will always be less than the elasticity in absolute value terms ($I < -\varepsilon$). This is because the credit subsidizes not only induced marginal R&D ($RD_1 - RD_0$), but also the infra-marginal R&D that would be performed regardless of the credit (RD_0).[13]

Kim (1996), on the other hand, divide induced R&D spending by the value of credits claimed during the year. We omitted Shah (1994) altogether since its incrementality calculation relies on a short run elasticity.

[13] $I \approx -\varepsilon$ for minute changes to the credit.

Before applying our conversion, the median of reported estimates is 1.3. Using the above approach to standardize the estimates, Table 1 reveals that the median incrementality for Canada is 0.86 and the average 0.91 when ϕ = 0.206, as calculated in Annex 1. We select the median incrementality ratio of 0.86 as an input to our model. The implications of an incrementality ratio that is less than one are discussed in section 5.

2.2 Spillover Benefits of R&D

Even with corporate attempts to protect their investment through secrecy and through intellectual property rights that can last decades, it is almost impossible for firms to fully appropriate the returns to their R&D efforts. Once an idea has been created, other firms can free-ride off the R&D efforts of the first firm by imitating its innovations. This 'non-rival' nature of R&D means that there are 'spillover' or 'external' benefits to other firms beyond the private benefits accruing to the original innovating firm. The sum of the 'private rate of return' to the innovating firm and the 'external rate of return' benefiting other firms yields the 'social rate of return' to research. However, individual firms will tend to conduct less R&D than is socially optimal unless they are compensated for the spillover benefits they provide to others. The subsidy level should therefore reflect the size of the external rate of return. The median of the external rates of return derived from eight Canadian studies (Table 2) is used as a parameter in our model. Annex 2 summarizes international studies for comparison.

Table 1: R&D Price Elasticity and Incrementality Ratio Estimates, 1990-2006

	Study	Country	Period	Long Run Price Elasticity: Reported	Long Run Price Elasticity: Average	Incrementality Ratio: Reported	Incrementality Ratio: Avg. or adjusted
Canada	Klassen, Pittman & Reed (2004)	Canada	1991-97			1.30	1.30
	Bernstein (1998)	Canada	1964-92	-0.30	-0.30		0.28[2]
	Dagenais, Mohnen & Therrien (1997)	Canada	1975-92	-1.09	-1.09	0.98	0.89[2]
	Dep't of Finance Canada & Revenue Canada (1997)	Canada	1994			1.38 (survey)	1.38
	Lebeau (1996)	Canada (Quebec)	1977-93	-0.965	-0.97	0.90 to 1.06	0.81[2]
	Nadiri & Kim (1996)	Canada	1964-91	-1.01	-1.01		0.84[2]
	Shah (1994)	Canada	1963-83			1.8[3]	
Other Int'l	Bureau of Industry Economics (1993)	Australia	1987-89	-1[1]	-1.00	0.6 to 1.0	0.80
	Harris, Li & Trainor (2005)	Northern Ireland	1998-03	-1.28	-1.28		
	McKenzie & Sershun (2005)	OECD countries	1979-97	-0.7 to -0.9	-0.80		
	Mairesse & Mulkay (2004)	France	1980-97	-2.68 to -2.78	-2.73	2 to 3.6	2.80
	Bloom et al (2002)	OECD countries	1979-97	-1.09	-1.09		
	Parisi & Sembellini (2003)	Italy	1992-97	-1.5 to -1.8	-1.65		
	Cornet & Vroomen (2005)	Netherlands	2000-01			0.5 to 0.8	
	Poot et al (2003)	Netherlands	1996-98	-1.12	-1.12	1.01 to 1.02	1.02
	Bureau Bartels (1998)	Netherlands				1 to 2 (survey)	1.50
	van den Hove et al (1998)	Netherlands	1994-96			0.70 to 1.70	1.20
	Nadiri & Kim (1996)	Germany	1964-91	-1.11	-1.11		
	Nadiri & Kim (1996)	Italy	1964-91	-1.02	-1.02		
	Nadiri & Kim (1996)	Japan	1964-91	-1.05	-1.05		
	Nadiri & Kim (1996)	UK	1964-91	-1.04	-1.04		
	Nadiri & Kim (1996)	France	1964-91	-1.05	-1.05		
	Asmussen & Berriot (1993)	France	1985-89			0.26	0.26
US	Bernstein & Mamuneas (2006)	US	1954-00	-0.12 to -1.33			
	Wilson (2006)	US	1981-02	-2.6	-2.60		
	Klassen, Pittman & Reed (2004)	US	1991-97			2.96	2.96
	Mamuneas & Nadiri (1996)	US	1956-88			0.95[3]	
	Nadiri & Kim (1996)	US	1964-91	-1.09	-1.09		
	Berger (1993)	US	1982-85	-1.0 to -1.5[1]	-1.25	1.74	1.74
	Hall (1993)	US	1981-91	-2.0 to -2.7	-2.35	2.0	2.00
	McCutchen (1993)	US	1982-85	-0.25 to -10.0[3]		0.29 to 0.35	0.32
	Hines (1993)	US	1984-89	-1.3 to -2.0	-1.65		
	Baily & Lawrence (1992)	US	1981-89			1.30[3]	
	Tillinger (1991)	US	1980-85			0.19	0.19
Entire Sample		Median			-1.09		1.25
		Average			-1.22		1.29
Canada Only		Median			-0.99	1.3	0.86
		Average			-0.84		0.91
US Only		Median			-1.26		1.52
		Average			-1.43		1.42
Canada & Other Int'l		Median			-0.96		0.96
		Average			-1.09		1.09

Source: Compiled by the authors. All estimates are derived from econometric studies, except the two with the word 'survey' beside them. These studies are presented in more detail in Annex 2. [1]Indicates a reported elasticity that we assumed to be a long run elasticity. [2]Calculated by authors using equation (2) where Ø = 0.206; other estimates taken from study, and no adjustments performed on non-Canadian estimates. [3]Incrementality ratios known to be short run estimates are omitted from median and average calculations, and McCutchen (1993) omitted from elasticity calculations given very wide range.

Before turning to studies that measure spillovers (i.e., that calculate an external rate of return), their definition needs to be further clarified. A first distinction to be made is that a firm can benefit from R&D conducted by other firms abroad (international spillovers) or within its home jurisdiction (domestic spillovers). The benefits to other countries of R&D performed in Canada, and the benefits to Canada of R&D performed outside Canada, may be economically important but are not relevant to an evaluation of the SR&ED tax credit. From a Canadian tax policy perspective, the primary interest is the benefits to Canada of R&D conducted in Canada, i.e. the private rate of return and the *domestic* external rate of return.

A second distinction is between domestic spillovers that flow among firms in the same industry (*intra*industry spillovers) and domestic spillovers that flow between firms in different industries (*inter*industry spillovers). Although this breakdown does not matter in our model, it is relevant when interpreting the literature, as few studies report a readily useable domestic external rate of return. Table 2 details the two kinds of adjustments we made.[1] Canadian industry-level studies that report the *inter*industry component of the domestic external rate of return (e.g. Mohnen & Lepine, 1991) require us to add an estimate of the *intra*industry component in order to derive the domestic external rate of return. Similarly, country-level studies that report the domestic social rate of return to R&D (e.g. Griffith, Redding and Van Reenen, 2004) oblige us to subtract an estimate of the private rate of return to the firm to derive the domestic external rate of return. In both cases, we make the adjustment using conservative estimates by Bernstein (1988) who did a firm- and industry-level study.

This discussion would be incomplete without describing the main methodologies used to measure spillovers. A common approach in the literature is to specify a production

[1] Several other distinctions were made when interpreting the literature. First, some industry-level studies report a 'private rate of return to industry', which could be described as the private rate of return to the firm plus *intra*industry spillovers. Second, studies use 'spillover', 'external' and 'indirect' synonymously. Third, some literature reviews lump external rate estimates together with social rate estimates, though one is really a component of the other.

function with traditional factors such as labour and capital, along with technological change inputs including 'own' R&D and 'outside' R&D stocks.[2] This allows changes in, for example, a firm's production to be attributed to changes in R&D conducted by the firm itself and to changes in R&D conducted by other firms. Cost functions provide an alternative methodology, where the size of the spillover is found by estimating the amount by which outside-firm R&D stocks reduce firm costs.

The median of the domestic external rates of return derived from the studies in Table 2 is 56 percent. Aside from removing the effect of outliers, it turns out that taking the median value has the added advantage in this case of being independent of the *intra*industry adjustment we made to several studies. Annex 2 provides an overview of estimates of domestic social, external and private rates of return for other countries, but several survey articles are worth mentioning here. Our 56 percent spillover rate is roughly in line with Nadiri (1993) who reviews 21 U.S. and Canadian studies published 1974-91 and concludes "the indirect and social rates of return often vary from 20 percent to over 100 percent with an average somewhere close to 50 percent" (p. 35). Our estimate is below the rate implied by Wieser (2005) who reviews 14 industry-level studies from the U.S., Canada, Japan and the U.K published over the same period and calculates an average domestic social return of 90 percent. Park (2004) estimates even higher domestic external rates of return to R&D for 14 OECD countries, ranging from 52 percent in Germany to 260 percent in Australia, with a median of about 85 percent.

[2] The authors of the studies in Table 2 and Annexes 2 and 3 typically generate R&D stocks by adding up R&D expenses over time and applying an assumed depreciation rate.

Table 2: Canadian Estimates of External Returns to R&D Investment, 1988-2004
(Nominal, gross of depreciation and tax, in percentages)

	Park (2004)	Griffith, Redding & Van Reenen (2004)	Bernstein (1997)	Bernstein & Yan (1997)	Bernstein (1996)	Mohnen & Lepine (1991)	Bernstein (1989)	Bernstein (1988)	Mean	Median
Sample Period	1980-95	1974-90	1966-89	1962-88	1964-86	1975-83	1963-83	1978-81		
Unit of analysis	Country	Country	Industry	Industry	Industry	Industry	Industry	Firm/ Industry		
Estimated Parameter (a)	Domestic Social Return	Domestic Social Return	Inter Industry Spillover	Inter Industry Spillover	Inter Industry Spillover	Domestic Social Return	Inter Industry Spillover	Domestic Spillover		
	160	70	113	124	38	86	16	9[1]	74	78
Adjustment (b)	-Private Return	-Private Return	+Intra Industry Spillover	+Intra Industry Spillover	+Intra Industry Spillover	-Private Return	+Intra Industry Spillover	-		
	-22[2]	-22[2]	+7[3]	+7[3]	+7[3]	-22[2]	+7[3]	-		
Domestic External rate of Return (a)+(b)	138	48	120	131	45	64	23	9	72	56
Domestic External Rate of Return without Intra-Industry Spillover Adjustment	138	48	113	124	38	64	16	9	69	56

Source: Compiled by authors. Notes: [1]Combines Bernstein's (1988) estimates of the intra (7%) and interindustry (2%) components of the domestic external rate of return. [2]Based on Bernstein's (1988) estimate of an 11.6 percent firm-level rate of return plus an assumed 10 percent depreciation rate (see Annex 1 for a detailed description of this rate). [3]Taken from Bernstein's (1988) estimate of the *intra*industry component of the domestic external rate of return, net of depreciation.

Domestic External Rate of Return = *intra*industry spillovers + *inter*industry spillovers.
Domestic Social Rate of Return = Private Rate of Return + Domestic External Rate of Return.
This table contains studies we knew to contain statistically significant estimates.

While the above empirical studies strongly suggest the presence of market failure in the provision of R&D, many economists are sceptical about specific estimates of social returns and spillovers. Griliches (1979), the founder of the R&D and productivity literature, gives a "plea for realism" (p.113) on what the production function can tell us about the return to R&D. But despite measurement and estimation problems, there still appears to be a general consensus that spillover effects from R&D are large, although they may vary from one industry or firm to another.[1]

Jones and Williams (1998) attempt to reconcile the empirical literature with the new growth theory. They argue that most of the empirical work relies on neoclassical assumptions, where R&D is simply treated as another input to the production process, and ignores some of the concepts that are formalized in the new growth theory, such as inter-temporal knowledge spillovers (spillovers from previous stocks of ideas) and congestion externalities (duplication of effort). They conclude that these effects on average likely raise the true social return, and hence the spillovers, well above the estimates given in the empirical literature. Griffith, Redding and Van Reenen (2004) support this conclusion, arguing that existing U.S.-based studies underestimate the return to R&D by ignoring the role of technology transfer.

2.3 Opportunity Cost of Public Funds

As with any tax incentive, the SR&ED tax credit has an opportunity cost, namely the forgone tax revenue that could have instead been used to lower other taxes or raise government spending. In our framework, the opportunity cost of funding the SR&ED credit is the benefit associated with a general reduction in taxes.[2]

[1] For example, Boadway and Tremblay (2003) suggest that existing firms might generate larger spillovers from their research than startup firms.

[2] It is equivalent to consider the cost of the credit to be the cost of raising taxes so that government revenues are unchanged. It is also equivalent to consider the opportunity cost to be the benefit of increasing spending, assuming that the government has equalized the marginal benefit of increasing spending and the marginal cost of raising taxes.

The benefit of lowering taxes by one dollar can be summarized in one measure: the marginal cost of public funds (MCF).[3] The first benefit to the private sector is the extra dollar of resources they receive from a one-dollar reduction in taxes. If the government could raise revenue without affecting efficiency (i.e. through lump-sum taxation), this benefit would be the only one available.[4] In reality, however, lowering taxes also comes with an additional efficiency benefit. Taxes distort economic behaviour – including the decisions to save, invest and work – which reduces efficiency and overall economic output. Therefore, a one-dollar reduction in taxes results in reduction in the marginal excess burden (MEB) or marginal efficiency loss caused by taxation. Combining the dollar-for-dollar transfer and the MEB gives the MCF of the R&D tax credit (i.e. MCF = 1 + MEB).

For example, instead of introducing an R&D tax credit, the government could reduce personal income taxes. This would not only transfer resources from the government to individuals, it would also reduce labour-leisure and consumption-saving distortions, resulting in an improved allocation of resources between consumption, saving and labour. Therefore, when the MCF is taken into consideration, the government must earn a return from the tax credit that is larger than what could be earned by lowering taxes instead.

According to a Canadian general equilibrium model developed by Baylor and Beauséjour (2004) of the Tax Policy Branch, Finance Canada, the corporate income tax generates a marginal excess burden of 0.4 for every dollar raised, while the personal income tax and the value-added consumption tax generate MEBs of 0.3 and 0.1 respectively. MCF figures reported by Dahlby (2005), based on previous studies, imply that every dollar raised through the corporate income taxes likely incurs an MEB of 1.0, whereas the personal income tax system likely incurs an MEB of 0.4. The MEB we use as a parameter in the model is 0.27, which is the average of the MEBs calculated for each tax by Baylor and Beauséjour (2004), weighted by the share of federal revenue obtained

[3] See Browning et al (2000) for a detailed overview and derivation of alternative MCF measures.
[4] In this case, there is no net welfare effect because the one dollar gain to the private sector is equivalent to the one dollar loss to the government.

with each tax in 2004.[5] This MEB estimate, which is equivalent to an MCF of 1.27, has been stable over the period 2000-2004 and is consistent with the values used in some other evaluations.[6]

2.4 Administration and Compliance Costs

The SR&ED tax credit program typically involves technical assessments, rigorous documentation, and an often-complex determination of which expenditures qualify. As such, in evaluating the SR&ED program, it is important to account for the cost of compliance. A previous evaluation of the SR&ED compliance costs was released in 1997 by Finance Canada and Revenue Canada. Surveying recipients of the SR&ED credit in 1994, they find that the cost of complying with the requirements for securing SR&ED tax support varied significantly by the amount of credits claimed and by whether it is a first time application or an ongoing application. We focus on ongoing claims since the program has been in place for a long time. For small claims of less than $100,000, the cost of compliance totalled 15 percent of the total value of SR&ED credits claimed. Firms with medium-sized claims of $100,000 to $500,000 reported a 10 percent compliance cost, while large claims (>$500,000) were associated with a 5.5 percent cost of compliance.

Applying these costs to 2004, we calculate a weighted average compliance cost of 7.9 percent (see Table 3).[7] Given the complexity of R&D tax claims, it is not surprising that our estimate of the SR&ED tax credit compliance cost is higher than that of the overall

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5 This choice of MEB reflects the assumption that all taxes in the mix would be lowered proportionally if the SR&ED were eliminated. An alternative approach would be to use the MEB of the most distortionary tax source, implying the assumption that the most distortionary tax would be the first to be lowered if the SR&ED were eliminated. Due to the relatively more distortionary nature of certain taxes, it would be more difficult to justify a subsidy, on R&D or anything else, on efficiency grounds if the alternative method were used.

6 For example, Australian R&D tax incentive welfare analyses summarized in Annex 4 used similar MEBs, ranging from 0.275 to 0.325.

7 This is significantly higher than the overall 0.7 percent average compliance cost found by Gunz et al (1996) based on a survey of 51 R&D performing firms in Ontario representing 30% of Canadian claims. However, the authors acknowledge their survey was hindered by the small sample and the poor response rate from small firms – the ones most likely to report high compliance costs. Indeed they found that “firms with claims under $200,000 have compliance costs in the area of 15 percent or more”.

tax system.[8] It is important to note, however, that the application form for small claims was simplified after the survey, likely reducing the compliance costs for small claims below the amount reported. On the other hand, anecdotal evidence suggests that R&D performing firms are willing to pay substantial portions of their credits to third party firms who make the claim on their behalf, at least in the first year of claiming the credit.

Table 3: Compliance Cost of the Federal R&D Tax Credit, 2004

	Cost (% of Credit)	Weight by value of credits granted
Small claims (< $100K)	0.150	0.14
Medium claims ($100K-$500K)	0.100	0.24
Large claims (>$500K)	0.055	0.62
Weighted Average Cost	0.080	

Source: Data from Finance Canada and Revenue Canada (1997) and Cortax Database, calculations by authors

The cost of administering the SR&ED program is also relevant. The Canada Revenue Agency estimates that total operational spending associated with the program, plus employee benefits such as employer sponsored pension and health plans, amounted to $48 million in fiscal year 2004/05. Dividing this by the accrued value of SR&ED tax credits granted in 2004 (see Annex 1) gives total administrative costs of about $0.017 per dollar of the credit. Combining the compliance costs and administration costs gives a total administrative and compliance cost of about 10 cents per dollar of tax subsidy on the program.

[8] For example, Slemrod & Blumenthal (1993) found a compliance cost of 2.6 percent of tax revenue raised using a sub-sample of Fortune 500 companies in the U.S. See Evans (2003) and Alarie et al (2006) for reviews of tax compliance costs studies.

3. A Model for Evaluating the Welfare Impact of Federal SR&ED Tax Incentives

Equipped with empirical estimates of our parameters, the welfare impact of federal R&D tax incentives can now be evaluated. The starting point is a scenario where the credit is financed with a lump-sum tax and where there are no market failures, demonstrating the familiar result that a subsidy leads to a net welfare loss in the 'base case'. The analysis is then extended to accommodate spillovers from R&D, distortionary taxation, and administration and compliance costs, demonstrating that the net welfare change can be positive or negative depending on the parameter estimates chosen.

3.1 Base Case: No Externalities and No Tax Distortions

Consider a representative firm with a single input, R&D stock, which we will denote as K. Each unit of K has an implicit user cost *(uc)* and generates a private return (R_p). R_p is equivalent to the marginal product of R&D capital (MPK), defined as the additional output generated per unit increase in capital. The representative firm will invest in K up to the point where the user cost of capital $uc = R_p$ at K_o. See Figure 1. Suppose the government introduces a subsidy (s), lowering the cost of K to $uc - s$ and leading the firm to set $K = K^1 > K_o$. To determine the welfare change associated with subsidy s, we need to examine whether the increase in producer surplus is greater than the cost of the subsidy.

If the tax incentive can be financed with non-distortionary taxes, the social cost is simply the total amount spent by the government on the subsidy. In our revenue neutral framework, it represents the reduction in private sector output following imposition of a lump-sum tax to finance the subsidy.

$$SC = sK^1 = \text{Area (aced)} \tag{3}$$

The gain the firm receives from being able to employ each unit of K at a lower cost is known as the producer surplus. In this case, the increase in producer surplus generated by the subsidy is the following, where I represents the additional K generated per dollar of subsidy:

$$\Delta PS = K_o s + 0.5\ (K^l s - K_o s)$$

$$= 0.5\ (K^l s + K_o s)$$

$$= 0.5\ [K_o\ (1+ sI\ )s + K_o s] \quad \text{as } K^1 = K_0(1+sI)$$

$$= K_o s\ (1 + 0.5sI\ ) = Area\ (abed) \tag{4}$$

The total welfare change as a result of the subsidy is simply the producer surplus (equation 4) less the social cost (equation 2). It is clear from Figure 1 that the subsidy yields a welfare loss equal to the Area (bce):

$$\Delta W = K_0 s(1+0.5sI)\ \text{ - } sK^l$$

The total welfare change *per dollar* of tax subsidy is:

$$\frac{\Delta W}{sK^1} = \frac{K_0 s(1+0.5sI)}{\mathrm{s}K^1} - 1 \tag{5}$$

Note that since, $\frac{K_0}{K^1} = \frac{K_0}{K_0(1+sI)} = (sI+1)^{-1}$

we can write (5) as: $$\frac{\Delta W}{sK^1} = \frac{1+0.5sI}{1+sI} - 1 \tag{6}$$

Equation (6) implies that the producer surplus per dollar of subsidy is less than one, leading to a net welfare loss. This result confirms the standard conclusion that, in the absence of externalities, government subsidies lower welfare since the gain in producer surplus in the subsidized firms is lower than the loss to other firms, which must pay for the subsidy.

3.2 Introducing Externalities

The spillover benefits that firms receive from another firm's R&D is known as the external return (R_e). The sum of the private and external returns gives the social return to R&D (i.e. $R_s = R_p + R_e$). As before, the representative firm will invest in K up to the point where $uc = R_p$ at K_o. But note, in Figure 1, that from a social standpoint the firm's decision is suboptimal since social welfare is maximized at the point where $uc = R_s$.

Suppose the government chooses the optimal subsidy rate, where $s = R_e$, inducing the firm to set its R&D stock equal to the socially desirable level, K^*. To determine the net welfare gain associated with subsidy s, we need to look at the gain from the external returns in addition to the producer surplus. In Figure 1, the gain from having additional external returns generated is:

$$\Delta ER = R_e(K^* - K_0)$$

$$= R_e sIK_o = \text{Area (fceb)}$$

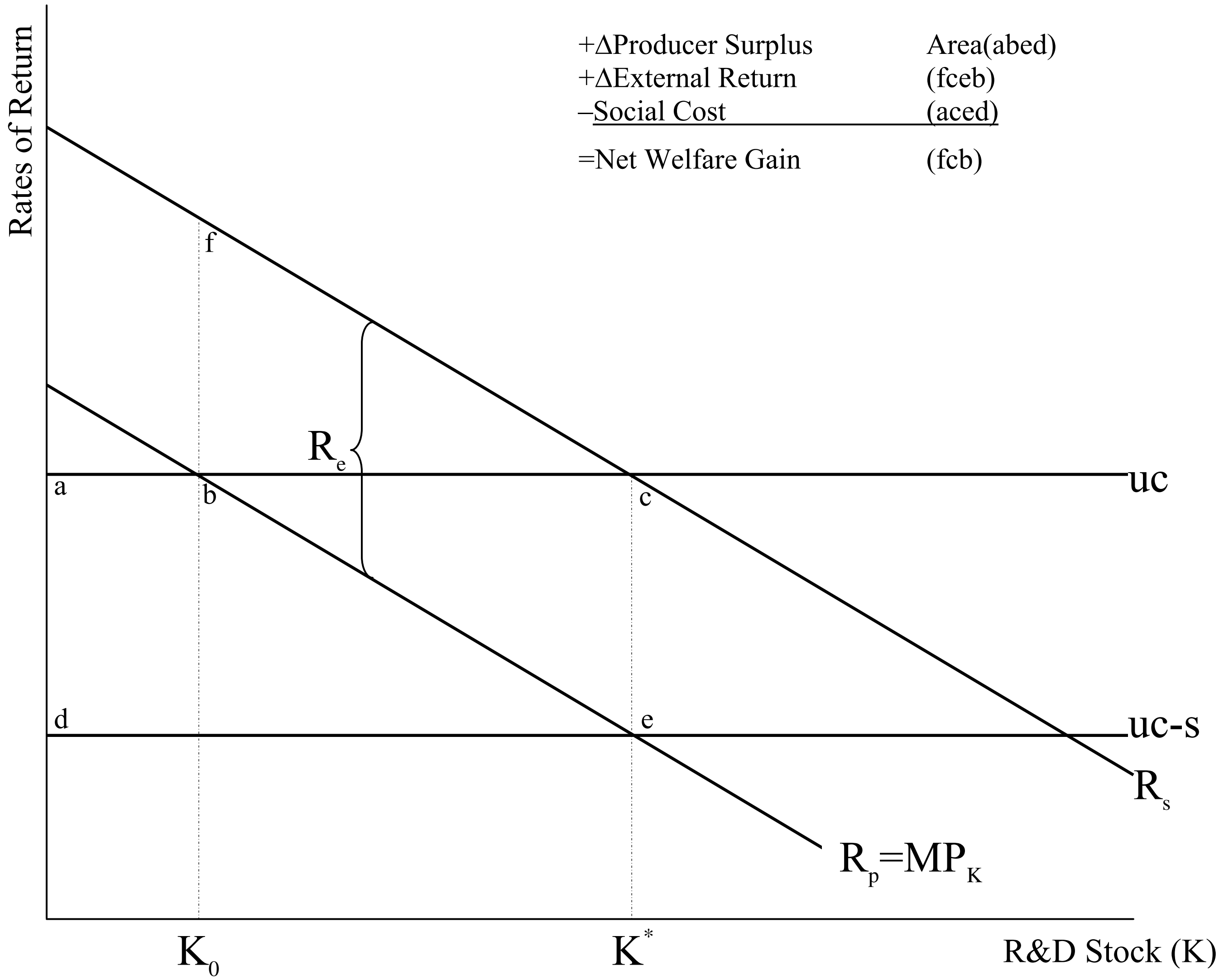
Per dollar of tax subsidy, the welfare gain from the external return is

$$\frac{\Delta W_{ER}}{sK^*} = \frac{R_e sIK_o}{\text{sK}^*} = \frac{R_e I}{1+\text{s}I} \tag{7}$$

Adding the external return component (equation 7) to the base model (equation 6) yields:

$$\frac{\Delta W}{sK^*} = \frac{1+0.5sI}{1+\text{s}I} - 1 + \frac{R_e I}{1+\text{s}I} \tag{8}$$

Figure 1: Optimal R&D Stock under Non-Distortionary Taxation and Externalities



3.3 Financing with Distortionary Taxation

In reality, proportional as opposed to lump-sum taxes are used to finance tax expenditures. Such taxes distort the allocation of resources and therefore impose a welfare loss on the economy. This means it costs society more than one dollar to raise one-dollar's worth of tax revenue. Some minor modifications to the above model will allow us to account for the welfare cost of raising taxes to finance the credit.

In addition, we must now account for the fact that tax revenues increase as a result of the extra *K* undertaken, which was not the case under lump sum taxation. The extra tax revenue (*TR*) generated is:

$$\Delta TR = tR_e(K^* - K_o) = tR_e sIK_0 \tag{9}$$

where t represents the tax rate on the external return generated from R&D.
Per dollar of tax subsidy, equation (9) becomes:

$$\frac{\Delta TR}{sK^*} = \frac{tR_e sIK_0}{sK^*} = \frac{tR_e I}{1+sI}$$

Since additional revenue has been generated, tax revenue does not need to be raised by the same amount as the subsidy. For a one-dollar R&D subsidy, the required increase in tax revenues is:

$$\frac{\Delta TR}{sK^*} = 1 - \frac{tR_e I}{1+sI}$$

Recall that the marginal excess burden (*MEB*) is the welfare loss associated with a one-dollar increase in tax revenues from a particular tax base:

$$MEB = \frac{\Delta W_{EB}}{\Delta TR}$$

Therefore, multiplying the MEB by the additional tax revenue required to finance a one-dollar subsidy gives the excess burden associated with financing the R&D tax incentive:

$$\frac{\Delta W_{EB}}{sK^*} = MEB\left(1 - \frac{tR_e I}{1 + sI}\right) \tag{10}$$

Adding the cost of distortionary taxes (equation 10) to the model with externalities, as represented by equation (6), gives the following welfare change per dollar of tax subsidy:

$$\frac{\Delta W}{sK^*} = \frac{1 + 0.5sI}{1 + sI} - 1 + \frac{R_e I}{1 + sI} - MEB\left(1 - \frac{tR_e I}{1 + sI}\right) \tag{11}$$

To prove our result, note that if we set $MEB = 0$ (i.e. taxes cause no distortion), equation (9) becomes equation (6), the case with lump-sum taxes.

3.4 Adding Administration and Compliance Costs

As previously discussed, the cost of administering and complying with the SR&ED program is significant and therefore should be added to the welfare analysis. The welfare loss associated with this cost is given by $A + C$, which represents administration and compliance costs per dollar of subsidy. In addition, since administrative costs are borne by the government, they must be financed with distortionary taxes. This raises the amount of taxes that must be raised to finance one dollar of tax subsidy on the program by A. Incorporating administrative and compliance costs, the total welfare change *per dollar of tax subsidy per year*,[9] becomes:

$$\frac{\Delta W}{sK^*} = \underbrace{\frac{1 + 0.5sI}{1 + sI} - 1}_{\text{Net change in Producer Surplus}} + \underbrace{\frac{R_e I}{1 + sI}}_{\text{Externality}} \underbrace{- MEB\left(1 - \frac{tR_e I}{(1 + sI)} + A\right)}_{\text{Tax Distortions}} \underbrace{- (A + C)}_{\text{Admin \& Compliance Cost}} \tag{12}$$

Equation (12) represents our partial equilibrium model for evaluating the welfare gain from a federal tax subsidy on R&D.

[9] In our framework, the tax expenditure associated with the SR&ED tax credit in year *i* is $TE_{iR} = RD_i * \varphi_i$, where RD_i is eligible SR&ED expenditures in year *i*. Since our tax expenditure includes an estimate of the present value of carry-forwards, it is calculated on an accrual basis. This is in contrast to the tax expenditure estimates published by Finance Canada (2006), which reports the cash value of credits claimed.

4. Results for the Federal SR&ED Tax Credit

4.1 Parameter Values

Using equation (12) from section 3, along with parameter estimates appropriate for the Canadian economy, the average welfare gain/loss per year per dollar of tax subsidy on the Federal SR&ED tax credit can be calculated. The parameter values used here are as follows. Note that Annex 4 compares parameters used in other evaluations.

- The long run **R&D incrementality ratio** is set to 0.86, the median of the ratios derived from the Canadian studies surveyed in Table 1 in section 2.1. This is a conservative estimate, since it is below American and other international estimates in Table 1 and Annex 2.
- The **domestic external return to Canadian R&D** is set to the median value of 56 percent calculated from the Canadian studies examined in Table 2 in section 2.2. As shown in Annex 2, this is comparable to estimates for other OECD countries, although the median US estimate is unexpectedly lower.
- The **marginal excess burden** from distortionary taxation is set to 0.27, an average of the MEBs calculated by Baylor and Beauséjour (2004) for each type of tax, weighted by the federal government's reliance on each tax (see section 2.3).
- As discussed in section 2.4, the **costs of compliance and administration** are assumed to be $0.08 and $0.02 per one dollar of tax subsidy, respectively.
- The **tax rate** on the domestic external return to R&D is set to 0.30,[10] the economy-wide average tax rate.
- The **R&D subsidy rate**, defined in our model as the reduction in the user cost of R&D as a result of the credit, is calculated to be 4.3 percent, taking into

[10] Represents total Canadian tax revenue, from all levels of government, as a percentage of nominal GDP in 2004 and 2005. It is calculated using Statistics Canada CANSIM tables 380-0001 and 385-0005. We use an economy-wide rate because the benefits from the additional R&D will raise labour income as well as corporate profits. This income will be taxed by all levels of government in Canada, allowing other taxes – such as personal, property or corporate taxes – to be lowered.

consideration the differing treatment of large and small firms. Refer to Annex 1 for a detailed calculation of this rate.

4.2 Results

Using the above parameters, the welfare gain per dollar of tax subsidy is calculated in Table 4. The table reveals that the spillover effect more than offsets the tax distortions and compliance costs associated with the R&D tax incentives. Overall, the estimated net welfare gain per dollar of tax subsidy on the SR&ED program is 0.109. This represents economic well-being created each year as a result of the ongoing SR&ED.[11] Given a tax subsidy of $2.9 billion, as calculated on an accrual basis for 2004 in Annex 1, this would imply a net welfare gain of over $300 million for each year the subsidy is in place.

Table 4: Calculation of the Welfare Effect Per Dollar of Tax Expenditure

Base Case -- No Spillovers or Tax Distortions	
Increase in Producer Surplus (1)	0.98
Social Cost of the Subsidy (2)	-1.00
Net Welfare Change (3)= (1)-(2)	-0.02
Spillover Effect[a] (4)	0.46
Tax Distortions	
Required Additional Tax Revenue[b] (5)	0.88
Excess Burden per $1 of Tax Revenue Raised (6)	-0.27
Total Excess Burden (7) =(5)*(6)	-0.24
Administration and Compliance Costs (8)	-0.10
Net Welfare Change (3)+(4)+(7)+(8)	0.11

a. As shown in equation 12, this is calculated as the domestic external return multiplied by the change in the R&D stock.

b. The net revenue loss is less than one because the credit generates additional output, which is taxable.

[11] Economic well-being is not quite the same as wealth, GDP or GNP since it is derived from a model that assumes full-employment and puts a value on leisure as part of well-being.

4.3 Sensitivity Analysis

When interpreting the results, it is important to note that they are sensitive to some of the parameter assumptions. This sensitivity can be demonstrated by seeing how much a single parameter can be altered before it would reverse our finding of a net welfare gain. For example, under our framework, the 56 percent estimate of the domestic external rate of return would have to fall to 45 percent to generate a welfare loss. Similarly, the 0.86 estimate of the incrementality ratio would have to fall to 0.71 to result in a welfare loss. Table 5 provides welfare estimates for various combinations of these parameter values, including cases where both parameters are changed simultaneously.

Table 5: Sensitivity Analysis of Net Welfare Gain Per Dollar of Subsidy

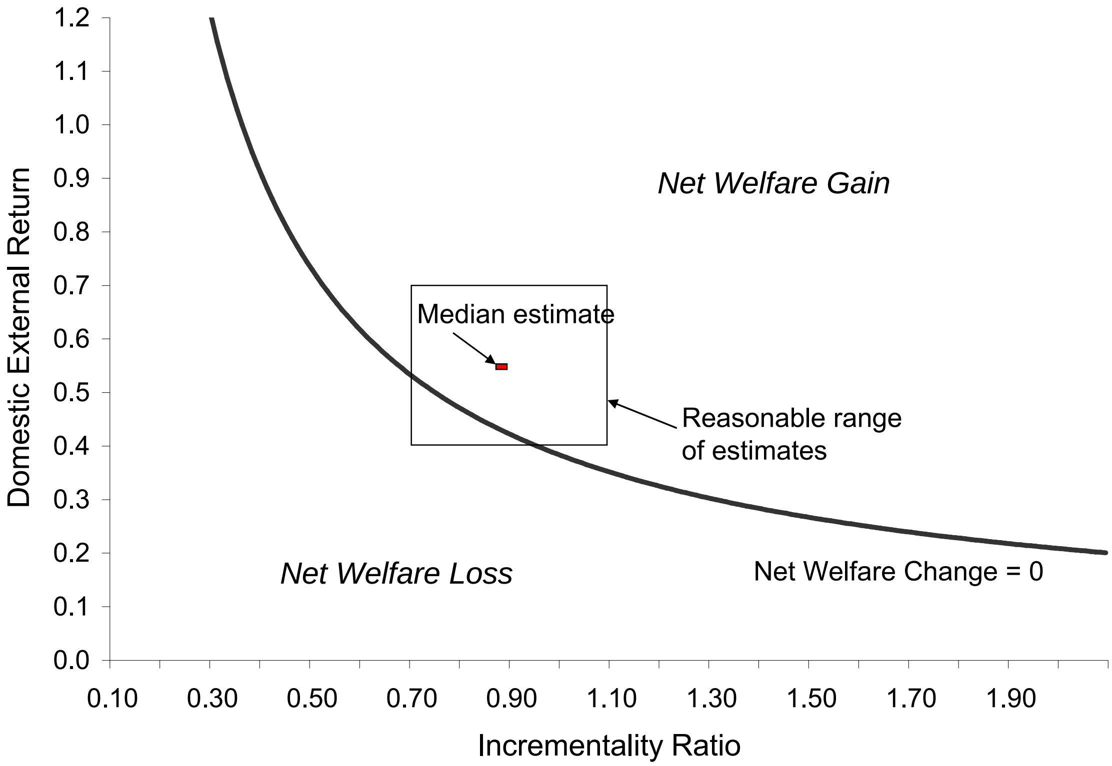
Incrementality Ratio	External Return								
	0.35	0.40	0.45	0.50	**0.56**	0.60	0.65	0.70	0.75
0.50	-0.201	-0.174	-0.148	-0.121	-0.090	-0.068	-0.042	-0.016	0.011
0.70	-0.133	-0.096	-0.059	-0.023	0.021	0.051	0.087	0.124	0.161
0.86	-0.079	-0.035	0.010	0.055	**0.109**	0.145	0.189	0.234	0.279
1.10	-0.001	0.056	0.113	0.170	0.238	0.283	0.340	0.397	0.454
1.30	0.064	0.130	0.197	0.264	0.343	0.397	0.463	0.530	0.596

The shaded rectangle corresponds to our 'reasonable' range of parameter estimates, while our point estimates are in bold.
Assumes *MEB* = 0.27, t = 0.3, s = 0.043

If these parameter combinations were matched with information on the probability distribution of each parameter, then the probability that the tax credit generates a net welfare gain could be calculated. However, there are too few Canadian studies (six incrementality studies, eight spillover studies) to yield reliable probability distributions. The modest number of studies, along with the wide range of estimates they report, imply large standard deviations such that confidence intervals at conventional levels of significance would be very broad. To create more useful confidence intervals, we must apply some judgement. From the incrementality studies in Table 1 it is apparent that half of the estimates are clustered very close to the 0.86 median, but there is a wide range from 0.28 to 1.38. We therefore judge that the median +/- 0.2 is a 'reasonable' range, equivalent to an 80 percent confidence interval if all incrementality studies are used, or a 90 percent confidence interval if the studies with the two most extreme estimates are excluded. From the spillover studies in Table 2 it is clear that the range is even broader for that parameter (from 9 to 138 percent) and there is less clustering near the median of 56 percent, suggesting we should adopt a wider confidence interval. We therefore judge that the median +/- 15 percentage points is a 'reasonable' range, implying a confidence interval of 60 percent regardless whether the extreme values are dropped. These 'reasonable' ranges, represented by the shaded area in Table 5, permit a crude assessment of the likelihood that the tax credit generates a welfare gain.

The boundary line in Figure 2 shows the combinations of incrementality ratios and domestic external rates of return that yield a net welfare gain/loss of zero, keeping all other parameters fixed at their default values – e.g. the marginal excess burden of taxation is left at 0.27. The area *above* the line represents parameter values that lead to a welfare gain, while values *below* the boundary line are associated with a welfare loss. The range of incrementality ratio estimates (0.7 to 1.1) and external return estimates (40 to 70 percent) that are considered reasonable for the Canadian economy are represented by the rectangle in Figure 2. The analysis reveals that the bulk of plausible parameter estimates lie above the boundary line in Figure 2. Therefore the majority of parameter estimates, based on a review of the literature, lend support to the notion that Canada's SR&ED tax credit has generated a net welfare gain.

Figure 2: Welfare Effects of the Federal SR&ED Tax Credit

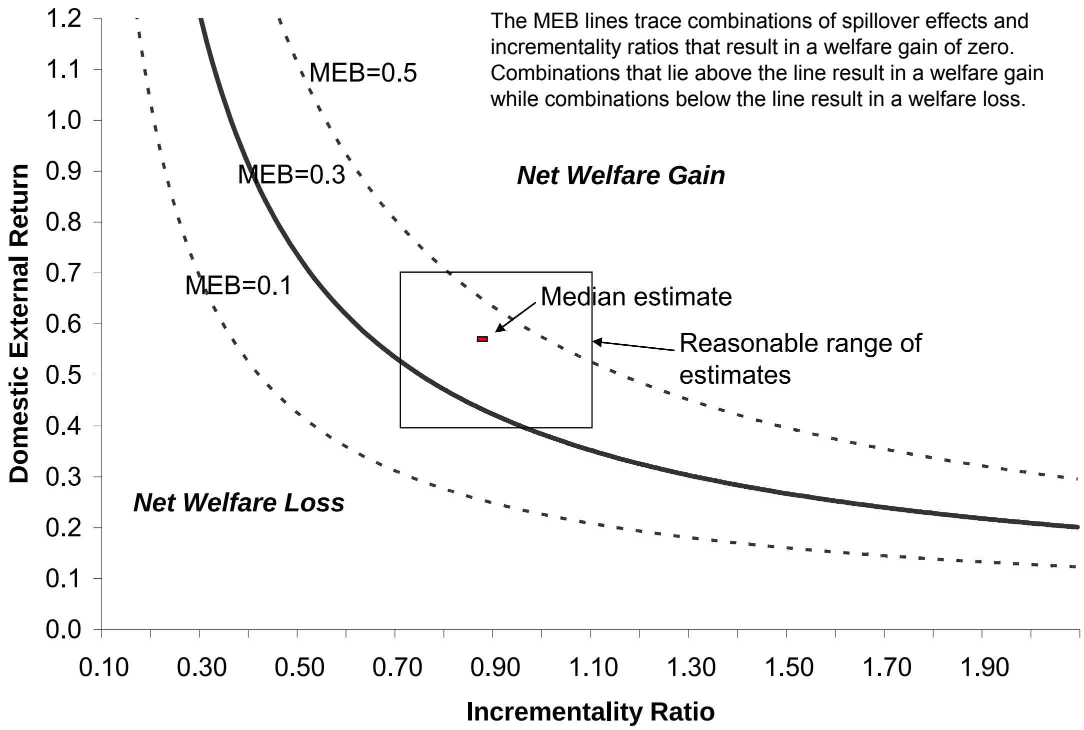


Assumes *MEB* = 0.27, *t* = 0.3, *s* = 0.043

Figure 3 extends the sensitivity analysis to include illustrative changes in the marginal excess burden of taxation. As mentioned in section 2.3, we assume that by offering the tax credit the federal government forgoes the opportunity to lower all taxes proportionately, and so our MEB of 0.27 is an average, weighted by federal revenue shares, of the individual MEBs for each type of tax. If instead the alternative to the SR&ED tax credit were lowering a relatively non-distortionary tax, say with a marginal excess burden of only 0.1, then the tax credit would yield an overall welfare gain for the entire range of 'reasonable' incrementality and spillover parameter values. In contrast, if the alternative were lowering relatively distortionary taxes, say with a marginal excess burden of 0.5, then one would have to assume incrementality ratios and external returns in the upper half of the reasonable range in order to generate a welfare gain. For a more specific example, if the alternative were lowering corporate income taxes for which

Baylor and Beauséjour (2004) estimate a marginal excess burden of 0.4, then our point estimate of the welfare gain would still be positive but with a lower level of confidence.[12]

Figure 3: Sensitivity of SR&ED Welfare Effects to Illustrative Changes in the Marginal Excess Burden (MEB)



Assumes $t = 0.3$, $s = 0.043$

[12] McKenzie (2006) reminds economists that investment in R&D is a function not just of targeted tax incentives but also of the overall corporate income tax on the benefits that flow from that research, and raises the question of the appropriate tax mix. In part this question is implicitly addressed by the sensitivity analysis above that shows the tax incentive is likely to generate a somewhat larger welfare gain than a revenue neutral reduction in the corporate income tax. Russo (2004) similarly finds that R&D tax credits would have a more positive welfare impact than a revenue neutral reduction in the corporate or personal income tax rate, based on his Computable General Equilibrium (CGE) model and parameters.

5. Discussion

5.1 Evaluating the Model Used

While our partial equilibrium framework allows for an intuitive and tractable decomposition of the welfare effects, it ignores some other channels of influence that a general equilibrium type model may be able to capture, given adequate information. Several such 'channels of influence' are summarized below. Overall, the direction of the bias created by our simplifying assumptions is difficult to predict, so we do not attempt to compensate.

First, since the analysis is based on a closed economy model, it does not capture investment account and terms of trade effects. As an example of an investment account effect, certain Australian studies (See Annex 4) remove from welfare the portion of R&D investment profits that are repatriated to non-resident shareholders. It would also have been appropriate to add intellectual property licensing fees received by Australians to obtain the net effect on welfare. In the case of Canada, the net effect is difficult to predict but it could well be positive: Statistics Canada (2006) reports Canada's net 'Technological Balance of Payments' showed a positive balance of more than $1 billion in 2003.[13] Terms of trade effects are also difficult to assess. Investment in R&D lowers costs and this would result in some combination of higher profits or lower prices, with the weight depending on the extent to which there is a 'world price' for the firm's output.

A second point related to open economy considerations is that additional R&D undertaken in Canada may improve the capacity of domestic firms to adopt foreign innovations, which would boost the net gain. Coe and Helpman (1995) suggest that this channel of influence may cause the welfare gain to be larger in a small open economy than in larger economies.

[13] Statistics Canada (2006) describes the technological balance of payments (TBP) as "the summary of all transactions relating to the purchase and sale of technological services, information and rights which are recorded in a country's balance of payments. It is an indicator of the flow of proprietary technology into or from a country."

Third, the labour supply decision of R&D workers may also affect the analysis. Some researchers have found that the supply of R&D workers is relatively unresponsive to changes in compensation, at least in the short or medium-term. As a result, the observed tax credit-induced increase in R&D expenditure may be more nominal than real, since increased demand for R&D workers may drive up their wages (see Goolsbee 1998 and 2003; David & Hall 2000; Wolff & Reinthaler 2005; Ballot et al 2002; Marey & Borghans 2000; and Berger 1993). By omitting this factor, the additional R&D stock stimulated and the associated spillovers may be overstated.

Fourth, the spillover effects of R&D used in this study may be understated. As described in section 2.2, the empirical estimates of spillovers are based on a neoclassical theory of R&D investment. While attempting to reconcile this approach with new growth theory, Jones and Williams (1998) conclude that empirical estimates likely significantly understate the true social return since R&D raises the value of knowledge over time. If so, R&D would affect the growth rather than the level of efficiency. In general, models that treat innovation as endogenous tend to find higher social benefits to research than the empirical literature (Russo, 2004). By relying on empirical estimates, therefore, we may be understating the welfare gain.

A final consideration is that financing constraints are not captured in our approach, which may cause an understatement of the responsiveness of R&D spending to changes in its price, lowering the welfare gain. Our framework is based on a neoclassical model of R&D investment where firms can borrow freely to reach their optimal R&D stock. In general, however, capital markets for financing R&D are imperfect as a result of asymmetric information –firms typically have more information about the profitability of their R&D projects than outside financers. This stems from the uncertainty of returns, the technical nature of R&D projects and the unwillingness of firms to disclose information to investors in fear of imitation by competitors. Asymmetric information, combined with the lack of collateral associated with R&D projects (e.g., salaries account for a large portion of R&D spending), implies that some firms investing in R&D have difficulty raising external financing and are often forced to rely on their own, and often very limited, internal funds.[14]

Since our user cost framework assumes perfect capital markets, the ability of the SR&ED tax credit to help firms overcome financing constraints (e.g. through its refundability provisions for small firms) may not be fully captured in the user cost elasticity estimates for at least two reasons. First, many firm-level studies analyze only publicly traded firms, which are less likely to face financing constraints.[15] Second, researchers often include a cash flow variable in R&D investment regressions based on the idea that tax incentives may influence R&D through a different channel – by raising the after-tax cash flow available to financially constrained firms. To the extent that the cash flow variable is picking up some of the effect of the credit, the user cost elasticity may understate the credit's true impact on R&D.

5.2 The Optimal Tax Credit Rate

Our results beg the question –is the optimal value of the federal SR&ED credit higher or lower than its current level? While the analytical framework allows an assessment of whether, *on average*, Canada is better or worse off with the credit, it cannot be used to calculate whether the subsidy should be increased or decreased. Deriving the optimal credit rate would require equating its *marginal* benefit with its *marginal* cost, which would require using marginal parameters instead of average or constant parameters.[16] While financing costs and the price responsiveness of R&D are measured at the margin, spillovers and administrative and compliance costs are average measures. As discussed in Annex 2, there is no consensus on whether there are increasing, decreasing or constant returns to scale in research at the national level. Lattimore (1997, p. 110) notes that "we

[14] See Hall (2002) for a review of the literature on the financing of R&D. Empirical evidence of R&D financing constraints is provided by Himmelberg and Peterson (1994).

[15] For example, Dagenais, Mohnen & (1997) use a Compustat database of publicly traded Canadian firms to estimate the elasticity of R&D investment.

[16] Dahlby (2005) calculates the optimal provincial R&D subsidy by deriving the MCF of provincial R&D taxation and setting it equal to the MCF of alternative taxation – the condition for an optimal taxation system.

do not have a strong basis for the notion that spillover returns associated with the marginal projects induced by the incentive are lower (or higher) than the average estimates generated by econometric and case studies."

5.3 Are Tax Credits the Best Way to Deliver Support for R&D?

Support for research does not have to be delivered indirectly via tax credits. Government could engage in direct assistance, through grants to the private sector or through publicly performed (university or government) research. Based on the most critical parameters in our framework, direct assistance could be considered to generate a superior welfare gain compared to tax credits *if* one of the following conditions are met, *all else equal:*

1. First, measured using the incrementality ratio, direct assistance would need to leverage at least as much private research as tax credits. After all, it would be counterproductive to increase direct assistance if firms regard it as a substitute for their own funding, and respond by spending less of their own resources on research (the 'crowding out' hypothesis). On the other hand, direct assistance may be complementary with private funding (crowding in) or may have no effect on private funding. Theory is ambivalent, so the question can only be answered empirically.[17]

2. The second condition is that spillovers (i.e. the domestic external rate of return) from direct assistance would need to be at least as large as the significant spillovers that tax credit-induced private research is believed to generate. Again, theory is ambivalent, so we must turn to the empirical literature. We examine direct assistance through grants and through publicly performed research in turn.

[17] This is the conclusion reached in a modeling exercise by David & Hall (2000), although they do identify some factors, such as the size of the direct assistance, which may effect whether complementarity or substitutability effects would be likely to dominate.

This review finds that direct assistance in the form of grants appears likely to leverage more research (crowding in) than tax credits, but also appears likely to generate lower spillovers, with an ambiguous net effect on welfare; i.e., neither of the above conditions is met on an 'all else equal' basis. On the question of crowding in or out (condition 1), we examined comprehensive literature reviews by David, Hall & Toole (2000) and Garcia-Quevedo (2004), as well as several recent additions to the literature (see Tables 12 and 13 in Annex 3). Those reviews refrain from drawing a firm conclusion, but note that just over half of the studies find complementarity, while the rest find either no effect or substitutability (crowding out). The most recent literature reveals the same pattern, but adds that the finding of an average effect of complementarity across firms may be driven by a subset of sensitive firms, such as those with a certain level of technology, cash flow, size, ownership structure, or experience performing research. This finding suggests that grants could conceivably be targeted to firms with relatively high incrementality ratios, although the literature is not yet in agreement on which firms should be targeted, such as small or large firms.

On the question of spillovers (condition 2), we examined literature reviews by Nadiri (1993) and Capron & van Pottelsberghe (1997), supplemented by other recent studies (see Table 13 in Annex 3). The weight of the evidence indicates that publicly financed private research likely has a less significant impact on productivity than privately financed research.

Direct assistance in the form of publicly performed research has not been studied as thoroughly by researchers, but the evidence implies a similarly ambiguous conclusion. Recent multi-country studies by Falk (2006), Wolff & Reinthaler (2005) and Guellec & van Pottelsberghe (2003) indicate that the effect on private spending is more likely to be negative (crowding out) or negligible than positive. However, the limited evidence also indicates that spillovers are likely to be larger,[18] with the exception that a survey by

[18] Park (1995) and Bassanini & Scarpetta (2001) find no impact and a negative impact respectively of publicly performed research on productivity, while Mamuneas & Nadiri (1996) and Guellec & van Pottelsberghe (2004), who use more appropriate models, find that publicly performed research has a greater impact on productivity than privately performed research.

Salter & Martin (2001) does not confirm the common notion that returns to publicly performed basic research may be unusually high.

The ability to draw firm conclusions from the literate is further eroded by considerations such as whether the research is defence or civilian research[19] and by interaction effects. Researchers find that both direct and indirect assistance leverage less private spending when the levels of the assistance are variable over time.[20] And while undue weight should not be placed on uncorroborated recent findings, there is some evidence suggesting that using direct and indirect assistance jointly may undermine their effectiveness, that there may be increasing returns to privately performed research, that there may be increasing or decreasing returns to grants depending on their level, and that returns to private research may be rising over time relative to returns to publicly performed research.[21] We conclude that there is presently *no evidence-based reason* to choose between tax credits, grants and publicly performed R&D as alternative ways to deliver support for R&D.

[19] See Guellec & van Pottelsberghe (2003 & 2004) and Poole & Bernard (1992).
[20] See Hall & Van Reenen (2000), Capron & van Pottelsberghe (1997), and Guellec & van Pottelsberghe (2003).
[21] These interactions are observed by Capron & van Pottelsberghe (1997), and Guellec & van Pottelsberghe (2003 & 2004).

6. Conclusion

This study evaluated the federal tax credit for investment in SR&ED, employing a framework that incorporated spillovers from investment in R&D, the price sensitivity of R&D investment (incrementality), the change in producer surplus, administrative and compliance costs, and the cost of financing the credit with distortionary taxes. The point estimate is a positive welfare effect of about 11 cents per dollar of revenue forgone. While this may appear to be a modest return, it is roughly equivalent to the government investing funds raised by distortionary taxes, which have an effective return of -30%, in an asset generating a 41% return. More generally, this analysis highlights the fact that an input to production must generate spillovers in excess of the efficiency loss associated with taxation in order to warrant a subsidy.

It is difficult to determine whether the partial equilibrium framework used in this study under- or overstates the true welfare effect, so a sensitivity analysis was undertaken. The analysis shows that although the estimates are sensitive to the underlying assumptions the SR&ED tax credit likely generates positive net economic benefits under a reasonable range of assumptions.

Annex 1: Calculation of Subsidy Rate

In our framework, the subsidy rate (*s*) is the percentage point amount by which the SR&ED tax credit reduces the user cost (*uc*) on R&D stock (*K*). As shown in Patry & Lemay (2007), the *uc* on R&D capital can be expressed as:

$$uc = q(1-\phi)(1+\sigma)\frac{(R_f + \delta - \pi)}{1-u}\left[1-u+\frac{CT(1-u)}{R_f+\delta}\right] \tag{A1}$$

where q is the price of R&D capital relative to output, ϕ is the credit rate, σ the sales tax on capital inputs, R_f the cost of financing, δ the rate of economic depreciation, π the inflation rate, CT the capital tax rate, and u the corporate tax rate. From equation (A1), it is clear that the R&D tax credit reduces the user cost of capital (*uc*) by the percentage amount ϕ. Therefore, $s = uc\phi$.

As shown in Table 6, ϕ is calculated as the five-year average from 2000 to 2004 of the total value of SR&ED tax credits realized by firms over their total expenditures on R&D in Canada. For firms carrying forward their credits to future years (the maximum carry forward period is 10 years), we take the present value of credits by assuming the probability that the firm will claim in each subsequent year. This gives $\phi = 0.206$.

To derive an estimate of *uc*, we gross up Bernstein's (1988) estimate of the net private return to R&D stock (11.6 percent) by adding an assumed rate of depreciation of R&D stock (10%), yielding a *uc* of 21.6 percent. While dated, Bernstein's is the most recent Canadian study we are aware of that directly estimates the private return to R&D at the firm level. Longo (1984) arrived at a similar gross private return to the firm of 24 percent. Our depreciation rate assumption is consistent with the assumption employed by the authors of the Canadian studies mentioned in Table 2, is consistent with the typical practice of assuming a rate of 5% to 15% in the international studies surveyed in

Annex 2, and lies within the range of empirical estimates.[22] The gross of depreciation *uc* of 20.1 percent implies a subsidy rate of $s = 0.043$.

Table 6: Calculation of the SR&ED Tax Credit Subsidy Rate, 2000-2004

	2000	2001	2002	2003	2004
Eligible R&D Spending					
Small CCPCs	2,068	2,504	2,758	2,891	3,327
Other Firms	10,286	12,447	11,578	11,195	11,028
Total R&D (A)	12,353	14,951	14,335	14,086	14,354
Accrued Value of SR&ED Tax Credits Earned					
Small CCPCs (35% credit)					
Used in Current Year, including carry-back	640	784	870	969	1,085
Present Value of Carried Forward*	67	82	93	82	90
Subtotal	*706*	*865*	*963*	*1,051*	*1,176*
Other Firms (20% Credit)					
Used in Current Year, including carry-back	884	1,172	1,084	845	921
Present Value of Carried Forward*	854	883	862	923	892
Subtotal	*1,738*	*2,055*	*1,946*	*1,767*	*1,813*
Total Credit (B)	2,444	2,920	2,909	2,818	2,989
Average Credit Rate (C) = (B)/(A)	19.8%	19.5%	20.3%	20.0%	20.8%
5-year Average Effective Credit Rate	20.1%				

Source: Cortax Data, calculations by the authors.

*This is a present value calculation, based on an assumed probability that firms will benefit from carryforward in subsequent years. In the absence of survey evidence, we assumed an exponential probability distribution, that 100% of Small CCPCs will claim the refundable credit within three years and that 90% of all other firms benefit within 10 years (the maximum claim period). The illustrative lower probability for larger firms reflects the assumption that some firms will stay unprofitable over the ten years or go out of business. The discount rate used is the net private rate of return to R&D calculated by Bernstein (1988), discussed in this Annex.

[22] Some researchers have questioned the assumption that the R&D depreciation rate is exogenous, constant across industries, and constant over time, however there is no consensus on a superior assumption. Pakes & Shankerman (1978) estimate a range of R&D stock depreciation rates of 18% to 36%. Nadiri & Prucha (1996) estimate a 12% rate for the US manufacturing sector. Baruch & Sougiannies (1999) estimate a range of 5% to 24% for four US industries, or 11% to 20% overall. Ballester et al (2004) estimate a range of 12% to 18% for five US industries. Bernstein & Mamuneas (2006) estimate a range of 18% to 29% for four US knowledge-intensive industries. Huang (2006) uses a novel approach and U.S. data from 1953 to 1998 to report a preliminary estimate of the depreciation rate for the total manufacturing sector of 8%, and for four knowledge intensive industries of 1% to 14%.

Annex 2: Price Sensitivity and Spillover Estimates from the Literature

Price Elasticity and Incrementality Ratio Estimates

Table 7 summarizes information on studies around the world since 1979 that have estimated R&D price elasticities or incrementality ratios. They are listed in descending order by publication year. The Canadian studies in Table 2 are included, with added information. Several columns in Table 7 warrant elaboration:

Where the information was available, the “methodology” column reports whether the study used an econometric approach or a survey approach, and whether it used flows (expenditure) or stocks (which require assumptions about initial level and depreciation, in order to generate R&D capital stocks).

The “Price Elasticity” column reports the own price elasticity of R&D investment with respect to its after tax user cost: %ΔR&D / %Δ user cost of R&D. Although studies may use varying definitions of user cost, this is the general approach.[1] Where available, this column reports whether the estimated elasticity is for the short run or long run. Higher long run elasticities indicate that it takes time to adjust to a higher level of R&D.

The term “incrementality ratio”' is adopted in this paper as opposed to more common terms such as ‘cost effectiveness ratio’, ‘tax sensitivity ratio’ or ‘bang for a buck’ for reasons outlined in section 2.1. It is equivalent to the change in R&D spending divided by the amount of revenue foregone due to the tax incentive. Many studies do not specify whether these are short run or long run estimates.

[1] Here, change in R&D is an expenditure or flow, as opposed to a change in stock, although it can be shown that flow and stock elasticities are the same in the long-run along a balanced growth path. If R&D’s economic rate of depreciation is less than 100% per year, then elasticity estimates using the flow approach will be higher in the short run.

Table 7: Price Elasticity and Incrementality Ratio Estimates, 1979-2005

Study	Country	Methodology	Sample Period	Incrementality Ratio	Price Elasticity
Bernstein & Mamuneas (2006)	US	Econometric, 4 manuf. industries	1954-00		-0.12 to -1.33
McKenzie & Sershun (2005)	OECD countries	Econometric, 9 countries	1979-97		-0.2 to -0.3 (Short Run) -0.7 to -0.9 (Long Run)
Wilson (2006)	US states	Econometric, 51 states	1981-02		-1.7 (SR) -2.6[1] (LR)
Harris, Li & Trainor (2005)	Northern Ireland	Econometric, 11 manuf. industries	1998-03		-0.42 (SR) -1.28 (LR)
Cornet & Vroomen (2005)	Nether-lands	Econometric, firms	2000-01	0.5 to 0.8[2]	
Klassen, Pittman & Reed (2004)	Canada & US	Econometric, 58 Can. firms, 110 US firms	1991-97	Canada: 1.30 US: 2.96	
Mairesse & Mulkay (2004)	France	Econometric, 765 manuf. firms, stock approach	1982-96	2 to 3.6	-2.68 to -2.78[3] (LR)
Poot et al (2003)[4]	Nether-lands	Econometric, 1000+ firms	1996-98	1.01 to 1.02 (SR)	-0.11 (SR) -1.12 (LR)
Parisi & Sembellini (2003)	Italy	Econometric, 726 firms	1992-97		-1.5 to -1.8[5]
Independent Expert Group (2003)		Literature review			Median –0.85
Bloom, Griffith & Van Reenen (2002)	OECD countries	Econometric, 9 countries, 20 manuf. sectors, flow approach	1979-97		-0.14 (SR) -1.09 (LR)
Bureau Bartels (1998)	Nether-lands	Survey		1 to 2[6]	

[1] States included Washington DC. Wilson (2005) differentiated between the effect of a state's own R&D incentives and the competing effect of other state's R&D incentives. The results reported in the table exclude the latter, in order to be comparable with the rest of the results reported in this table. When other states' incentives were factored in, the estimated elasticities fell; R&D appeared to be moving between states with little net creation of R&D due to state-specific R&D incentives.

[2] These estimates correspond to the effect of a particular expansion of the Dutch tax credit, called the Starter program, which gives new technology firms an R&D researcher tax credit of 60% of wages instead of the 40% available to other firms. For another expansion, raising the first tax bracket from EUR 68 thousand to 90 thousand (after which point a lower 13% tax credit applies), they estimated an incrementality ratio of 0.2 with less confidence.

[3] The 95% confidence interval was -1.9 to -3.5.

[4] The elasticity estimates used a sample of 1751 R&D tax credit claimant firms. The incrementality ratio has a 95% confidence interval of 0.70 to 1.33, and used samples of 602 to 1042 firms. The Incrementality ratio was lower for larger than for smaller firms. Note that the Dutch tax credit reduces the tax liability of firms for researcher salaries, so the elasticity and incrementality ratio apply to firm spending on researcher salaries. This paper expands upon Brouwer et al (2002).

[5] Info from abstract and from Jaumotte & Pain (2005). For Table 1 we assume elasticity is long run.

[6] According to Cornet (2001a).

Study	Country	Methodology	Sample Period	Incrementality Ratio	Price Elasticity
van den Hove et al (1998)	Netherlands	Econometric	1994-96	0.70 to 1.70[7]	
Bernstein (1998)	Canada	Econometric, 11 manuf. industries	1964-92		-0.14 (SR) -0.30 (LR)
Dagenais, Mohnen & Therrien (1997)	Canada	Econometric, 434 firms, stock approach	1975-92	0.98	-0.07 (SR) -1.09 (LR)
Bloom, Chennells, Griffith &Van Reenen (1997)	Australia, Canada, France, U.S.	Simulation, 244 public U.K R&D performing firms	1989-93	Australia 0.54 Canada 0.28[8] France 0.18 U.S 0.82	Assumed -1
Mamuneas & Nadiri (1996)	US	Econometric, 15 industries, stock approach, private R&D	1981-88 1956-88	0.95	-0.94 to -1[9] (LR)
Lebeau (1996)	Canada (Quebec)	Econometric, 26 industries	1977-93	0.90	-0.97 (LR)
Abt Associates (1996)	Canada	Survey of 501 firms	1994	1.38	
Nadiri & Kim (1996)	Canada & G7	Econometric, 7 countries	1964-91		Canada: -1.01 (LR) G7: -1.01 to -1.11 (LR)
Shah (1994)	Canada	Econometric, 18 three-digit industries, stock approach	1963-83	1.80	-0.16 (SR)
Bureau of Industry Economics (1993)	Australia	Survey, 880 firms, flow approach	1987-89	0.60 to 1.00	Near -1[10] (SR)
Berger (1993)	US	Econometric 263 firms, flow approach	1982-85	1.74	-1.0 to -1.5
Hall (1993)	US	Econometric, 950 firms, flow approach, private R&D	1981-91	2.0	-0.8 to -1.5 (SR) -2.0 to -2.7 (LR)
McCutchen (1993)	US	Econometric, 20 large drug firms in 4 groups	1982-85	0.29 to 0.35	-0.25 to -10.0[11]

[7] According to Cornet (2001a) and (2001b).
[8] As these are simulations rather than empirical estimates, they are not included in Table 1.
[9] The incrementality ratio is from the 1981-88 sample period. Dagenais et al (1997) characterize the elasticity as short term.
[10] According to Hall (1995).
[11] According to Hall (1995).

Study	Country	Methodology	Sample Period	Incrementality Ratio	Price Elasticity
Hines (1993)	US	Econometric, 116 multi-nationals, private R&D	1984-89	1.2 to 1.9[12]	-1.2 to -1.6 (SR) -1.3 to -2.0[13] (LR)
Asmussen & Berriot (1993)	France	Econometric, 339 firms, flow approach	1985-89	0.26	
Swenson (1992)	US	Econometric, 263 firms	1981-85		Not reported
Baily & Lawrence (1992)	US	Econometric, 12 two-digit industries	1981-89	1.3[14]	-0.95[15] (SR)
Tillinger (1991)	US	Econometric, 506 firms	1980-85	0.19 (range 0.08 to 0.42)	Not reported
GAO (1989)	US	Econometric, 800 large firms	1981-85	0.15 to 0.36	Assumed -0.2 to -0.5
Cordes (1989)	US	Literature review	1981-85	0.35 to 0.93[16]	
Bernstein & Nadiri (1989a)	US	Econometric, 4 industries, total R&D	1959-66		-0.43 to -0.50 (LR)
UK HM & Inland Revenue (1987)	Several	Literature review		Roughly 0.5[17]	
Bernstein (1986)	Canada	Econometric, 27 firms, stock approach	1981-88	0.83 to 1.73[18]	-0.13 (SR) -0.32 (LR)
Mansfield & Switzer (1985a & 1985b)	Canada	Survey, 55 firms in 3 industry groups representing 30% of R&D	1980-83	0.38 (range: 0.11 to 0.67)	-0.04 to -0.18 (estimated from McFetridge & Warda (1983)
McFetridge & Warda (1983)	Canada	Econometric, aggregate	1962-82	0.6	-0.6 "tentative"
Mansfield (1985 & 1986)	Sweden	Survey, 40 firms	1981-83	0.34 (range: 0.3 to 0.4)	Small, but greater in LR
Mansfield (1986)	US	Survey, 110 firms	1981-83	0.30 to 0.60	-0.35, greater in LR
Eisner, Albert & Sullivan (1984)	US	592 firms	1980-82	Not reported	Insignificant result
Eisner, as reported by Collins (1983)	US	Survey, 99 firms	1981-82	Less than 1	Insignificant result[19]
Nadiri (1980)	US	11 manuf. industries	1958-75		-0.16 (SR) -1.0 (LR)

Source: Compiled by the authors.

[12] According to Conseil (1996).
[13] According to Wilson (2005). The higher absolute elasticities in each range correspond to the flow approach, while the lower corresponds to the stock approach.
[14] Conseil (1996) instead cites a figure of 2.4.
[15] According to Dagenais et al (1997) and Hall & Van Reenen (2000).
[16] Estimated impact of making the US tax incentive permanent.
[17] According to McFetridge (1995).
[18] 0.8 if output is held constant, or 1.05 to 1.73 if the impact of spillovers on output is considered (Dagenais et al, 1997).
[19] According to Hall (1995).

Studies summarized in Table 8 tested the response of R&D to changes in the b-index[20] rather than the user cost of R&D. These studies do not provide price elasticity estimates that can converted to incrementality ratios and used in our model, however they do serve as additional evidence that R&D is sensitive to fiscal policy incentives. For example, Falk (2006a) concludes that increasing R&D tax credits enough to lower the B-index by 1% would increase R&D intensity (R&D/GDP) in the business sector by 0.91% in the long run.

Table 8: B-index Elasticity Estimates

Study	Country	Methodology	Sample Period	Elasticity of BERD wrt B-index
Falk (2006a)	OECD countries	Econometric, 21 countries, flow approach	1980-02	-0.22 (SR) -0.84 (LR)
Czarnitzki et al (2004)	OECD countries	Econometric, 21 countries, flow approach	1985-02, five year averages	-0.75 (SR) -0.81 (LR) insignificant[21]
Guellec & Van Pottelsberghe (2003)	OECD countries	Econometric, 17 countries, flow approach	1983-96	-0.28 (SR) -0.31 (LR)
Ryan & Ridge (1999)	OECD countries	Econometric, 15 countries, flow approach	1995 for B-index, 1991-95 other variables	Wide range of insignificant estimates, strongest evidence of a negative elasticity for small countries

Source: Compiled by the authors.

[20] Warda (2004) has pioneered the use for R&D tax incentives of a comprehensive measure, called the B-Index, which measures the after-tax cost of undertaking US$1 of R&D in each OECD country. More specifically, the B-Index measures the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay corporate income taxes. Algebraically, it is equal to the after-tax cost of an expenditure of US$1 on R&D divided by one minus the corporate tax rate. The B-index differs from a marginal effective tax rate (METR) in that the METR measures the percentage change in the required rate of return on an investment due to all elements of the tax system (e.g. capital taxes, RSTs on capital inputs) not just those directly related to investment in R&D. In addition, the B-Index is calculated assuming that investment in R&D is 100 per cent equity financed, compared to 60 per cent in the METR methodology..

[21] These results are from the dynamic panel data model, the SR elasticity is significant, but the LR elasticity is derived from an insignificant coefficient on the lagged endogenous variable. When university lab research is excluded as an explanatory variable, the elasticities are -0.88 (SR) and -1.05 (LR). In the fixed effects model, not relying on the insignificant coefficient, the elasticity is a significant -0.60.

International Estimates of Private, External and Social Rates of Return

Table 2 in section 2.2 presents the Canadian estimates from which we selected the median domestic spillover rates. The assumptions made in order to apply this rate in our model and the adjustments made in order to standardize the rates from the literature are detailed below. This discussion is followed by Tables 9, 10 and 11 which serve as supportive evidence that the significant spillovers found in Canadian studies are not an anomaly.

The use in the model of a spillover rate derived from the literature implies two closely related assumptions that are standard in R&D program evaluations. These assumptions, discussed by Scherer (1983a) and Lattimore (1997), are considered reasonable in the absence of a compelling reason to adjust the spillover rate upward or downward.

The first assumption is that the *marginal* rate of return on induced investment in R&D is equal to the rate calculated by the studies in Table 2 and Table 11, which is the *average* rate of return on total R&D. Some researchers suggest that the marginal spillover rate should be lower than the average. For example, one could assume that spillovers are positively correlated with private returns, and that marginal private returns are likely to be lower for induced R&D than for infra-marginal R&D since the most profitable projects are likely to be chosen first. Another possible reason for a lower spillover would be if the existence of the R&D tax credit induced firms to reclassify non-R&D expenditure as R&D expenditure.[22] Others counter that, for example, to the extent that lower private returns reflect a lower ability to appropriate the social benefits, lower marginal private returns may indicate higher spillovers (negative correlation).

[22] Auditing of R&D claims suggests, however, this may not be a large problem. In addition, Bryant et al (1997), cited by Lattimore (1997), found a close correlation between Australian business R&D expenditure (as a share of OECD business R&D) and filing for patents abroad by Australian residents (as a share of OECD total). Lattimore interprets this as evidence that official R&D statistics likely reflected legitimate R&D. However, Bryant et al (1996) note that this correlation was not found for all countries in their OECD sample, which did not include Canada.

The second assumption is that the spillover rate of return is independent of the quantity of R&D conducted. The usage of a constant spillover rate assumes that private returns and social returns diverge by a constant amount. Figure 1 demonstrates this assumption, with a social rate of return that declines solely due to a declining private return. While there are alternative assumptions, e.g. a constant social rate and a diminishing private rate leading to an increasing spillover rate (Scherer, 1983a), there is little evidence to suggest that our constant spillover rate is unreasonable.

Not all of the studies in Table 2 explicitly reported a spillover rate of return; some only reported different rates of return in which spillover rates were implicit. In those cases, we derived spillover rates using the following relationships that are true by definition:

- Domestic spillover rate = domestic social rate – private rate of return to firm
- Domestic spillover rate = domestic intra + inter industry spillover rate
- Domestic social rate = worldwide social rate – international spillover rate

For many of the studies, it was necessary to assume a user cost to the firm (a gross private rate of return) in order to complete the derivations. Our welfare analysis is sensitive to this assumption, since a one-percentage point higher user cost results in a one-percentage point lower spillover rate. For reasons described in Annex 1, we assume a user cost of 21.6%.

Table 9 and Table 10 present domestic social rate of return estimates for the G7, the OECD, and the US, for comparison with Table 2. These US social return estimates are lower than expected, since we would have assumed that social rates would be higher in the US than in Canada given the US's presumably greater capacity to absorb a larger portion of the worldwide benefits of its own R&D.

Table 9: Social Return Estimates for the G7 and the OECD, 1995-2004
(Nominal, gross of depreciation and tax, in percentages, domestic)

Study	Sample Period	Countries	Social return	Countries ***	Social return
Griffith, Redding & Van Reenen (2004)	1974-90	G7	69	12 OECD	78
Luintel & Khan (2004)	1965-99	G7	123	10 OECD	132
Park (2004)	1980-95	G7	66	14 OECD	91
Van Pottelsberghe & Lichtenberg (2001)*	1971-90	G7	68	13 OECD	39**
Xu & Wang (1999)	1983-90	G7	70	21 OECD	50**
Coe & Helpman (1995)	1971-90	G7	122	22 OECD	94**
	Average		86		81
	Median		70		84

*Study sample excluded Canada. **These studies only reported a 'G7' and 'non-G7' estimate, so we constructed an OECD average weighted by the number of countries. Unadjusted rates are country medians. ***Includes G7 countries.
Source: Compiled by the authors.

Table 10: Social Return Estimates for the US, 1981-2004
(Nominal, gross of depreciation and tax, in percentages, domestic)

Study	Sample Period	Unit of analysis	Social return
Griffith, Redding & Van Reenen (2004)	1974-90	Industry	57
Luintel & Khan (2004)	1965-99	Country	175
Park (2004)	1980-95	Country	57
Wolf & Nadiri (1993)	1947-77	Industry	47
Bernstein (1996)	1964-86	Industry	80
Bernstein & Nadiri (1991)	1957-86	Industry	37
Bernstein & Nadiri (1989)	1965-78	Firm	23*
Bernstein & Nadiri (1988)	1958-81	Industry	28
Griliches & Lichtenberg (1984)	1959-78	Industry	61*
Scherer (1982)	1964-78	Industry	88
Sveikauskas (1981)	1959-69	Industry	50
All studies	Average		64
	Median		57
Post 1990 studies	Average		76
	Median		57

*Converted from net to gross by adding 10% depreciation
Source: Compiled by the authors.

Table 11 presents a broader range of estimates from around the world in greater detail. The wide range of estimates is indicative of the uncertainty surrounding these estimates, and helps motivate the sensitivity analysis undertaken in section 4.3. Table 11 also contributes to transparency by acknowledging the diversity of methodological choices underlying the estimates, which is not evident from the information presented in Tables 2, 9 and 10. For example, some studies regress total factor productivity (TFP) on R&D intensity and interpret the elasticity as the external rate of return, while other studies regress the log of sales on the log of R&D intensity and manipulate the elasticity to derive the external rate of return, and so on. In addition, Table 11 shows that while many studies have estimate elasticities without explicitly calculating a rate of return, the size and statistical significance of these elasticities provides further evidence of the size and existence of a spillover effect of private R&D investment. Finally, Table 11 includes the rates in the Canadian studies (highlighted with bold) in Table 2 as reported by their authors prior to our adjustments.

Table 11: International R&D Rates of Return & Elasticity Estimates

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Gelauff & Lejour (2006)	OECD / 14 countries, 12 sectors / 1980-99	TFP growth		Elasticity 0.049	Elasticity 0.074	
Bloom, Schankerman & Reenen (2005)	US / 736 firms / 1981-2001	Output	Elasticity 0.050[1]		Elasticity 0.123 (=2.5 * Private Firm)	Elasticity 0.173 (=3.5 * Private Firm), or 280%[2]
Cassidy, Gorg & Strobl (2005)	Ireland / Manuf. firms / 1999-2000	Output	Private Firm insignificant in SR			
Fukao & Kwon (2005)	Japan / 1000's of manuf. firms / 1994-2001	TFP	Elasticity 0.144			
Graversen & Mark (2005)	Denmark / 2,228 firms / 1991-2001	Output	Elasticities 0.018 to 0.114, yielding rates 11% to 34%[3]			
Harris, Li & Trainor (2005)	Northern Ireland / 11 manuf. industries / 1998-2003	Output		Elasticity 0.044 (range 0.03 to 0.17)	insignificant[4]	
Nishimura, Nakajima & Kiyota (2005)	Japan / Firms / 1994-2000	TFP	Elasticity 0.17 to 0.24			
Okada (2005)	Japan / 13,000 R&D and non-R&D performing firms / 1994-2000	Output (log sales) / R&D intensity (R&D expend. over value added)	Elasticity 0.23 to 0.61 (lower end of range for subsample of R&D performers)			
Rogers (2005)	UK / 719 firms / 1989-2000	Output	Elasticities 0.12 to 0.16; (marginal gross) returns 25% manuf., 24% overall[5]		Insignificant[6]	
Griffith, Redding & Van Reenen (2004)	OECD / 12 countries, 9 manuf. industries / 1974-90	TFP growth / R&D stock over value added		Elasticity 0.473		Gross: 69% Canada; 57% US; median 78%
Guellec & Van Pottelsberghe (2004)	OECD / 16 countries / 1980-98	TFP				
Higon (2004)	UK / 8 manuf. industries / 1970-97	TFP		Elasticity 0.331	Inter-industry Spillover 0.942 (= 3 * Industry Private)	
Karpaty & Lundberg (2004)	Sweden / 2000 manuf. firms / 1990-2000	TFP	significant[7]			
Kwon (2004a)	Japan / 12 manuf. industries / 1973-98	TFP		Elasticity 0.28; Kwon interpreted the marginal product of the R&D stock (the reported TFP elasticity) as the rate of return on R&D, i.e. 24%	insignificant	
Kwon (2004b)	Korea / 12 manuf. industries / 1985-96	Output	29% median		insignificant	
Kwon (2004c)	Japan / 34 manuf. Industries / 1970-98	TFP growth / change in R&D stock over gross output			insignificant	
Luintel & Khan (2004)	OECD / 10 countries / 1965-99					132% G7 average; insignificant Canada; 175% US
Mancusi (2004)	G7 / 6 countries, 135 manuf. industries / 1981-95	Output			Significant	
Park (2004)	OECD & East Asia / 14 OECD & 3 East Asian countries, manuf. & non-manuf. sector / 1980-95	TFP		Canada: 44% for manuf sector, 85.5% for non-manuf sector	116.2% spillover from manuf sector to non-manuf sector	Elasticities 0.12 manuf., 0.08 nonmanuf; yields returns of 160% from manuf. sector in Canada, 57% US; median of countries 119%[8]
Poldahl (2004)	Sweden / Manuf. firms / 1990-2000	Log TFP	Elasticity 0.01		Inter industry significant (elasticity 0.18), intra industry insignificant[9]	

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Tsai & Wang (2004)	Taiwan / 136 large manuf. firms / 1994-2000	Output	Elasticity 0.18 (0.30 for high tech, 0.05 conventional manuf., 0.07 all non-high tech); yields return of 24% overall (35% high tech, 9% other)		Spillover from high tech to other = elasticity of 0.01	
Bond, Harhoff & Van Reenen (2003)	UK & Germany / 200+ UK & 200+ German large manuf. firms / 1987-96					
Bond, Harhoff & Van Reenen (2003)	UK & Germ-any / 200+ UK & 200+ German large manuf. firms / 1987-96	Output	Elasticity UK 0.065; Germany 0.079 insignificant; implies returns of 38% UK; 19% Germany insignificant[10]			
Cameron (2003)	UK / Manuf. sector / 1960-95	TFP Level and Growth		Elasticity manuf sector 0.288 (range 0.2 to 0.3) in LR[11]		
Frantzen (2003)	OECD / 14 countries, 22 manuf. industries / 1972-94	TFP				Elasticity 0.29 in LR
Gu & Tang (2003)	Canada / 14 industries / 1980-97	Labour Productivity (GDP per hour worked)		insignificant		
Kwon & Inui (2003)	Japan / 3,830 manuf. firms / 1995-98	Log Labour Productivity (Y/L) / Log R&D over Labour	Elasticities 0.093 to 0.101; yield gross return 16%, insignificant net return			
Nakanishi & Inui (2003)	Japan / 68 industries / 1980-98	TFP		Elasticity 0.010[12]		
Ogawa (2003)	Japan / Manuf. firms / 1988-91 & 1999-2001	TFP	Huge range of elasticities (0.3 to 0.6 in 1988-91, 4.4 to 5.1 in 1999-01)			
Ballot, Fakhfakh & Taymaz (2002)	France & Sweden / 100 French firms, 200 Swedish / 1987-93	Log Labour Productivity (value added over labour)[13]		Elasticity 0.050 in France, 0.023 in Sweden		
Greenhalgh & Longland (2002)	UK / 740 firms / 1986-95	Log Output / R&D over tangible fixed assets	Elasticity 0.04 (0.07 for high tech, 0.02 for other)			
McVicar (2002)	UK / 7 manuf. industries / 1973-92	TFP		Elasticity 0.015 (range 0 to 0.050), as interpreted by Higon (2004);	Elasticity 0.076 (range 0 to 0.076) = 5 * Private	Elasticity 0.09 to 0.10
O'Mahony & Vecchi (2002)	US / 2,925 firms / 1988-97	DLog Output (net sales) / DLog R&D stock	Elasticity 0.113		significant	
Branstetter (2001)	US & Japan / 209 US firms, 205 Japan firms / 1983-89	Output	Elasticity 0.37 in US, insignificant in Japan		Elasticity 0.83 in US (= 2 * Private), and 0.70 in Japan	
Hubert & Pain (2001)	UK / 15 industries / 1983-92	Labour Productivity		0.029	0.032	
Van Pottelsberghe & Lichenberg (2001)	G7+ / 13 countries / 1971-90	TFP				Elasticity 0.017 (sample avg), 0.088 (G7 sub sample); yields return of 68% for G7, 15% for others[14]
Wilson (2001)	US / 55 industries (32 manuf.) / 1957-96	Output			insignificant[15]	
Cameron (2000)	UK / 19 manuf. industries / 1972-92	Log TFP / Log industry funded R&D over physical capital		Elasticity for manuf. sector 0.237 (range 0.117 to 0.367)		
Hanel (2000)	Canada / Manuf. industries / 1974-89	TFP			significant[16]	
Los & Verspagen (2000)	US / 680 manuf. Firms / 1974-93	Output	0.01 to 0.02, or 0.04 to 0.1 in high tech in LR		0.4 to 0.6 (= 4 to 30 * Private Firm)	
Mulkay, Hall & Mairesse (2000)	US & France / 482 US & 486 French / 1982-93	Output	0.05 (lagged) to 0.09 (current)			
Gera, Gu & Lee (1999)	Canada & US / 27 industries / 1971-93	Labour Productivity Growth		22% Canada; 7% US not robustly significant	Insignificant Canada & US	

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Makki, Thraen & Tweeten (1999)	US / Agriculture Industry / 1930-90			6% internal rate of return to privately funded R&D[17]		
Xu & Wang (1999)	21 OECD countries / 21 countries / 1983-90					
Xu & Wang (1999)	21 OECD countries / 21 countries / 1983-90	TFP				0.133 in G7 countries, 0.037 in non-G7 countries; yields return 70% G7, 40% others
Capron & Cincera (1998)	World / 625 manuf. firms / 1987-94	Log Output (sales)	0.13 to 0.33 for overall sample, or 1 to 2 * elasticity wrt private physical capital invest.		negative or insignificant for overall sample; 0.56 to 0.69 for US (= 2 to 3 * Private)	
Harhoff (1998)	Germany / 443 manuf. firms / 1979-89					
Harhoff (1998)	Germany / 443 manuf. firms / 1979-89	Log and DLog Output (Sales)	0.08 (within) to 0.14 (total) for overall sample, 0.13/0.16 for high tech & 0.10/0.09 for other;[18] yields net[19] returns 66% overall, 77% high tech, 38% for other			
Klette & Johansen (1998)	Norway / Manuf. plants / 1980-92		6% to 9% (plant level, net)			
Klette & Johansen (1998)	Norway / Manuf. plants / 1980-92	DLog TFP / DLog R&D capital	Private plant level elasticity 0.007 for first difference, 0.0140 for 3 year difference		likely significant[20]	
Bernstein (1997)	Canada / 10 manuf. industries / 1966-89			17.2%	113% (range 69% to 174%)	130% (range 86% to 191%)
Bernstein & Yan (1997)	Canada & Japan / 10 manuf. industries / 1962-88			(gross before tax) 17.2% Canada; 17.4% Japan	Median: 124% Canada; 41% Japan	141% Canada; 57% Japan
Frantzen (1997)	OECD / 21 countries, business sector / 1965-92	Output			Significant	
Sakurai, Papaconstantinou & Ioannidis (1997)	OECD countries / 10 countries, 7 manuf. & service industries / 1973-91			For manuf. sector, returns ≈20% for US & Japan and >20% for Canada & Italy		
Van Meijl (1997a and b)	France / 30 industries / 1978-92	TFP		Van Meijl (1997a and b) followed Terleckyj (1974) who interpreted the betas as rates of return, yielding 10% to 19% for Van Meijl (1997a), and 13% overall, 17% high tech for (1997b).	significant for Van Meijl (1997a), appears negative or insignificant for (1997b)[21]	11% to 13% for Van Meijl (1997b)[22]
Wakelin (1997[23])	UK / 170 large manuf. firms / 1988-92	Labour Productivity growth (sales over employees) / R&D expend. over sales		0.35[24]		significant
Adams & Jaffe (1996[25])	US / 80 firms & 1,400 plants in chemical industry / 1974-88	Output and Log TFP	Output elasticity 0.06 to 0.10 for firms, 0.01 to 0.03 for plants; TFP elasticity 0.06 to 0.08 for plants		significant	
Bernstein (1996)	Canada & US / 11 manuf. industries / 1964-86			(gross) 13% Canada; 16% US	Median: 38% Canada; 64% US	Median: 80% US
Bernstein & Yan (1996)	Canada & Japan / 10 manuf. industries / 1964-86	TFP				significant for Canada & for Japan[26]
Brat & Park (1996)	World / 59 countries / 1960-85	Labour productivity (output per capita)				Level: 0.124; Growth: 0.08 to 0.09 insignificant[27]
Cameron & Muellbauer (1996)	UK / Manuf. / 1962-92	Log TFP / Log stock privately funded R&D & technology royalties		Elasticity for manuf. sector ranges from 0.152 (insignificant) to 0.375 (significant)		

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Ducharme & Mohnen (1996)	Canada / Manuf. / 23 years	TFP			significant, implied by social	1.5 to 2 * Private[28]
Klette (1996)	Norway / 804 manuf. plants / 1989-90	TFP / R&D by firms in line of business that plant belongs to	0.014		significant spillovers between affiliated firms in the same industry	
Lichtenberg & Van Pottelsberghe (1996)	OECD / 22 countries / 1971-90	TFP				Elasticities 0.083 to 0.145; yields returns of 51% G7, 63% other
Nadiri & Kim (1996[29])	Canada & G7 / 7 countries / 1964-91	Output	(gross) 15% Canada; 14% to 16% G7			G7 country elasticities range from 0.63 in Canada to 0.83 in US in LR
Nguyen et al (1996)	US / Firm	TFP	significant	significant[30]		
O'Mahony & Wagner (1996)	UK / Manuf. / 1973-89			0%[31]		
Singh & Trieu (1996)	Japan, Korea & Taiwan / Country level / J: 66-91; K: 82-90; T: 78-90	TFP growth / basic, applied and experimental R&D expend over output.				significant in all 3 countries
Coe & Helpman (1995)	OECD / 22 countries / 1971-90	TFP				Elasticity 0.234[32] in LR; yields returns 122% G7,[33] 81% other
Adams & Jaffe (1994)	US / firms	Output			significant[34]	
Caballero & Jaffe (1993)	US	Output			significant but falling	
Suzuki (1993)	Japan / Manuf. firms / Not specified	Output			significant	
Wolff & Nadiri (1993)	US / 19 manuf. industries, and others / 1947-77			11% manuf.; 20% overall[35]	16% manuf.; 27% overall[36]	27% manuf.; 47% overall
Hall & Mairesse (1992[37])	France / 197 manuf. firms / 1980-87	Output	Elasticity 0.25; yields returns of 27% (net), 34% (gross)			
Lichtenberg (1992)	World / 57 countries / 1960-85	Output level and growth				privately funded R&D (0.073 or 0.066) = 0.4 or 0.2 * Social for physical capital (0.184 or 0.354)[38]
Mohnen (1992)	Canada / Manuf. sector /			Manuf. sector: 12%, gross[39]		
Odagiri & Murakami (1992)	Japan / Pharmaceutical industry & firms		19%	33%[40]		
Bernstein & Nadiri (1991)	US / 6 manuf. industries / 1957-86			22% median	15% median	37% median
Lichtenberg & Siegel (1991)	US / 2000+ manuf. firms / 1973-85	TFP	Elasticities 0.35 for privately funded R&D,[41] 0.10 to 0.13 overall; the authors interpret these coefficients on firm-level TFP regressions to be equivalent to the private rate of return, e.g. 35%			
Mohnen & Lepine (1991)	Canada / 12 manuf. industries / 1975-83			Gross: 56% average	Gross: 30% average	Gross: 86% industry average; median 63%
Yamada, Yamada & Liu (1991)	Japan / 7 manuf. industries / 1975-82	Labour Productivity (value added over employees)			0.124 to 0.163	negative for some industries, positive for others
Fecher (1990[42])	Belgium / Firms / 1981-83	TFP	insignificant		significant	
Bernstein (1989)	Canada / 9 industries / 1963-83			Gross: 29% median	Gross: 16% median	Gross: 42% median
Bernstein & Nadiri (1989)	US / 48 manuf. firms, 4 industries / 1965-78		Net: 7%		Net: 6% median intra-industry (range 2% to 8%)[43]	Net: 13% median (range 12% to 16%)
Goto & Suzuki (1989)	Japan / 40 firms / 1976-84	Output	40%		significant	
Sterlacchini (1989)	UK / 15 industries / 1954-84	TFP		0.1 to 0.2	significant	
Terleckyj (1989)	US		20% to 27%			

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Trajtenberg (1989)	US / Product innovation case study / 1972-1981					270% (ratio of benefits to costs, present value terms)[44]
Bernstein (1988)	Canada / 7 manuf. industries, 180 firms / 1978-81		11.6%		8% to 15%	20% median[45]
Bernstein & Nadiri (1988)	US / 5 manuf. industries / 1958-1981			Gross (of 10% dep.): 16% median	9% according to Bernstein & Nadiri (1988), *or 12% implied by difference between social and private medians*[46]	28% median (range 11% to 129%)
Hanel (1988)	Canada (Quebec) / 12 manuf. industries / 1971-82					
Hanel (1988)	Canada (Quebec) / 12 manuf. industries / 1971-82	Labour Productivity growth / R&D expend. growth		0.24, or 50% "Gross above normal" (due to double counting)	Significant[47]	0.36
Jaffe (1988)	US / 434 firms / 1972-77	DLog Output (sales, 5 year difference) / R&D stock over sales	0.03;[48] implies returns of 10% to 15% (gross excess)		marginally significant	
Mansfield (1988)	Japan / Manuf. industries / 1960-79	TFP		Elasticity 0.33, "crude" interpretation as 33%		
Jaffe (1986)	US / 432 firms / 1972-78		27% (gross)[49]			
Odagiri & Iwata (1986)	Japan / 168 firms / 1974-82		11%[50]			
Sveikauskas (1986)	US / Non-farm business sector / 1948-82	TFP growth		Private sector = significant[51]		
Griliches & Mairesse (1985)	Japan / 406 Japan firms, 525 US firms / 1973-80	Labour Productivity (sales over employees) / R&D over sales		0.248 to 0.562[52]		
Odagiri (1985)	Japan / Manuf. industries / 1973-77			3%[53]	insignificant[54]	
Clark & Griliches (1984)	US / 924 manuf. firms / 1970-80	TFP	18% to 20%			
Griliches & Lichtenberg (1984[55])	US / 193 manuf. industries / 1959-78, R&D data from 1974 only	TFP growth / own R&D and imported product R&D		Net: 11% to 31%	Net: 69% to 90%	Net: 41% to 62%
Griliches & Mairesse (1984)	US / 133 large firms / 1966-77	Output	Total & Between 0.05 to 0.07; Within 0.08 to 0.15			
Longo (1984)	Canada / 110 R&D intensive firms / 1980		24%[56]			
Griliches & Mairesse (1983)	US & France / 15 industries / 1967-78			25% gross excess		
Link (1983)	US / 302 firms / 1975-79	TFP	0.06, insignificant[57]			
Postner & Wesa (1983)	Canada / 13 manuf. industries / 1966-76	Labour Productivity growth / growth of own R&D stock and R&D embodied in inputs		insignificant	significant[58]	
Scherer (1983b)	US / 443 firms / 1964-78	Labour Productivity / own product and process R&D over sales		significant		
Griliches & Lichtenberg (1982)	US / 27 manuf. industries / 1959-73				Following Schankerman (1981), they interpreted the elasticity of TFP growth wrt R&D intensity as "social gross excess" (over private) rates of return: 36% (1969-73); 20.5% (1964-68); 5.6% (1959-63)	
Link (1982)	US / 97 manuf. firms / 1975-79	TFP / R&D expend. over net sales	0.312 to 0.538[59]			

Study	Country / Sample / Years	DepVar / IndepVar	Return to Firm	Return to Industry	Domestic External Return	Domestic Social Return
Scherer (1982)	US / 87 industries / 1964-69 & 73-78, R&D 1974 only			29% to 43% for product R&D	significant	71% to 104% for privately performed process R&D and imported product R&D
Sveikauskas & Sveikauskas (1982)	US / 144 manuf. industries / 1959-69, R&D data from 1971 only	TFP growth / R&D over labour		Elasticity 0.138 to 0.237		
Link (1981)	US / 51 large manuf. firms / 1973-78	Average TFP growth / private basic research over net sales	Elasticity 2.31 for private basic research			
Nadiri & Schankerman (1981)	US / Manuf. sector / 1958-78	TFP		Private manuf. sector significant		
Schankerman (1981)	US / 883 large firms, 6 manuf. industries / 1958-76			Gross: 51% average		
Sveikauskas (1981)	US / 144 manuf. industries / 1959-69	TFP growth / R&D over labour		0.171		50%, as interpreted by Griffith et al (2004)
Nadiri (1980)	US / 11 manuf. industries / 1958-75	Output		0.11 (0.19 non-durables, 0.075 durables); yields returns of 20% (gross) (12% durables, 86% non-durables)		
Schankerman (1979)	US / Manuf. firms / Early 1960s			3% to 5% (net excess, or risk premium) above assumed standard rate of 30%		
Globerman (1972)	Canada / 11 manuf. industries / 1959-68, R&D data from 1959-61 only	Output		0.357, not robustly significant[60]		
Lithwick (1969)	Canada / 10 industries / 1946-65, R&D data from 1955 only	Output for 1955-65, TFP for 1946-56 / R&D over sales[61]		Insignificant		
Minasian (1969)	US / 17 chemical firms / 1948-57		54%			

Legend: ‘Median’ indicates the study calculated estimates for multiple industries or countries, and the estimate reported here is the median; ‘Insignificant’ indicates results were statistically insignificant at the 10% level; ‘Significant’ indicates that results were statistically significant but not comparable due to e.g. variable definitions (we presumed that all other estimates were significant in the absence of explicit information to the contrary); ‘OECD’ refers to the Organization for Economic Cooperation and Development; estimates in decimal form are elasticities, estimates with percentage signs are rates of return; Canadian studies used in Table 2 are bolded.

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[1] I.e., a 1% increase in the R&D of all firms would lead to a 0.050% increase in economy wide sales from the direct private effect of that R&D, and an additional spillover effect of 0.123%. See Table 8, page 42.
[2] The authors call the “3.5 times” figure a “first approximation” and derive it from the ratio of the reported output elasticities. The authors do not derive the “280%” figure themselves, but they do observe that economy-wide sales would increase $2.7 billion in response to $965 million in R&D induced by an R&D tax credit tax expenditure of $870 million.
[3] For both the rate and the elasticity, the lower number corresponds to the sample of firms including non-R&D firms, and the higher number corresponds to the sub-sample excluding non-R&D firms. For the elasticity coefficient, the dependent variable is log value added, independent is log R&D capital.
[4] Dependent variable log real gross output, independent variable log R&D. The study only measured intra-industry spillovers between Northern Ireland and the United Kingdom.
[5] The author does not report the 24% figure, which is calculated using returns from Table 6 and weights from Table 5.
[6] See Table 4 of Rogers (2005).
[7] R&D expenditure was significant, but R&D intensity was not. Dependent variable log TFP.
[8] It is not clear from the study whether individual country results are statistically significant. Figures are gross; stocks constructed assuming 10% depreciation.
[9] Dependent variable is log TFP. The coefficient on the log index of inter-industry R&D was 0.18 in the preferred specification. Intra-industry R&D was insignificant.
[10] The returns were calculated from information on page 16 of Bond et al (2003).
[11] Found that a permanent increase in R&D will permanently increase the level but not the growth of TFP. Only privately funded R&D was used in the regression.
[12] Original paper is in Japanese. The figure is not quite significant and was cited by Fukao & Kwon (2004).
[13] Independent variable for France is portion of R&D workers as a proxy for stock, for Sweden it is R&D stock per employee.
[14] G7 excludes Canada. Only business sector R&D included.
[15] Wilson found suggestive but statistically insignificant evidence that embodied technological change is due to upstream R&D.
[16] Other industry R&D contributes 3 times more than own industry R&D to TFP growth. In other words, inter-industry spillovers are more important than intra-industry spillovers. Similar Canadian findings were made by Postner & Wesa (1983); Hanel et al (1986); Hanel (1988), Bernstein (1988); and Mohnen (1992b).
[17] Information taken from abstract. The return to publicly funded R&D in the agriculture sector was 27%.
[18] Those are the results when the dependent variable is log sales. Using DLog sales, with a long difference, the results are 0.10 for the sample, 0.16 high tech, insignificant for other.
[19] Harhoff (1998) page 43 indicates that net rates here are 3 to 4 * the gross rates.

[20] Klette et al (1998) estimate R&D stock depreciation at 18%, which they interpret as suggestive of significant spillovers.
[21] The study disaggregated R&D spillovers into different types preventing the reporting of a summary measure.
[22] These results appear to imply zero or negative spillovers. Van Meijl (1997b) did not discuss the social or spillover results in the text.
[23] This is a working paper version of Wakelin (2001), which uses a longer dataset (1988-96).
[24] This study used innovation flow weights. When firms in the sample are split into innovators and non-innovators, the Private elasticity is much higher for the non-innovators, and insignificant for the innovators. The coefficients on R&D intensity shrink and become insignificant when industry dummies are added. According to Higón (2004), the spillover rate calculated by Wakelin (2001) was 0%. According to Cassidy et al (2005), the private rate calculated by Wakelin (2001, p. 1084) was 27%, since "for every additional pound spent on R&D expenditure output would increase by £1.27 ceteris paribus".
[25] Info from abstract.
[26] Domestic R&D spillovers increase TFP growth in 8 of 10 Canadian industries and 8 of 10 Japanese industries. In those industries which are helped by domestic spillovers, domestic spillovers account for 21% to 100% (mean 43%) of TFP growth in Canadian industries, and 3% to 100% (mean 49%) in Japanese industries.
[27] Author suggests that domestic R&D has a greater effect on GDP level than growth.
[28] Info taken from Abstract since full text was not available. As a TFP study, it is unclear whether the relative "rates" reported in the abstract are based on relative elasticities.
[29] This is a working paper version of Nadiri & Prucha (1997).
[30] Info taken from abstract.
[31] According to Higon (2004).
[32] In other words, a 1% increase in domestic R&D stock leads to a 0.23% increase in domestic TFP.
[33] In other words, a $100 increase in R&D in a G7 country leads to a $122 increase in that country's GDP.
[34] Info from abstract.
[35] Private industry rates of return are higher when considering only privately funded R&D: 40% for manuf. and 60% for the entire sample.
[36] Spillovers reported here are those implied by the difference between social and private. Wolff & Nadiri tried estimating the spillover directly but did not obtain robustly significant results.
[37] This is a working paper version of an article published as Hall & Mairesse (1995).
[38] The alternative numbers apply to level and growth equations respectively.
[39] Notes that spillovers likely underestimated due to methodology.
[40] Information taken from the abstract. Implies intra-industry spillover of 14%.
[41] The return on privately funded R&D was found to be an increasing function of firm size.
[42] Info from Wakelin (1997).
[43] The spillover rates here were derived from social and private rates. Bernstein assumed 10% depreciation.
[44] Cost benefit ratios are not comparable to social rates of return calculated using IRR.
[45] The social rates of return in this study are net of 10% depreciation and include both intra and inter industry spillovers. Two-digit SIC industries were used, and the author took the cost function approach.
[46] The 12% spillover = median social – median private. However, median spillover = 9% according to Bernstein & Nadiri (1988) Table 3.
[47] Hanel (1998) found the impact of other industry R&D (0.5) to be at least twice that of own industry R&D (0.2). Mohnen (1992) interprets this as a spillover rate of 100%.
[48] The 0.03 elasticity implies that a $1 increase in a firm's R&D would increase its sales by 25 cents per year for the next 5 years.
[49] The gross private rate of return to physical capital was 15%.
[50] Or 17% without industry dummies. For the period 1966-73 with 135 firms the private rates were 17% with and 20% without industry dummies. Figures from CBO (2005) and Kwon (2003).
[51] The study does not actually report on statistical significance, however its findings are robust to sensitivity analysis. Specifically, R&D stock contributed 0.1% to 0.2% to productivity growth over the period.
[52] Coefficients fell in the lower end of the range when industry dummies were included. Kwon (2003) interpreted these coefficients as rates of return.
[53] According to Kwon (2004).
[54] According to Wolff & Nadiri (1993).
[55] The information here was taken from Wieser (2005), who credited Australian Industry Commission (1995), and says that social rates may not add up from industry and spillover rates since "those industries with the lowest (highest) rate of return to the industry may not be those with the lowest (highest) rate of return to firms in other industries".
[56] According to Mohnen (1992).
[57] According to Wieser (2005), who interpreted it as a rate of return. NSB (1996) instead cites a rate of return of 3%.
[58] A 1% "increase in an industry's growth rate of indirect intramural R&D content" leads to a 0.18% "increase in the own effects component of the productivity growth rate".
[59] The higher estimate corresponded to a measure of R&D that excluded R&D devoted to compliance with environmental regulation.
[60] Dependent variable is log output growth, independent variable is R&D performed within not purchased by firms /sales (R&D intensity). Results were insignificant for a larger sample of 14 industries.
[61] Independent variable R&D/sales. Dependent variable: output for 1955-65, TFP for 1946-56. Globerman (1972) was the source of this info.

Annex 3: Comparing Indirect and Direct Assistance for R&D

Section 5.3 summarized our investigation into whether there is an evidence-based reason to prefer indirect assistance for private R&D (i.e. tax credits) or direct assistance (i.e. grants for private R&D, or R&D that is publicly performed in government or university labs). Our general finding was that empirical evidence is still too ambiguous to draw a firm conclusion. In particular, we found that while there was weak evidence that direct assistance may have a somewhat larger incrementality ratio, this was offset by weak evidence that direct assistance may have a somewhat smaller spillover rate. The evidence we drew upon is presented in Tables 12 and 13 below. Table 12 contains multi-country studies of whether direct assistance encourages firms to cut back (crowding out, substitutability) or boost (crowing in, complementarity) their own private R&D spending. Table 13 contains single-country studies on the crowding out or in question, as well as studies addressing the existence and size of spillovers.

Table 12: Multi-Country Studies on Complementarity or Substitutability of BERD and Direct Assistance, 1999-2006

	Independent variable		**Empirical findings (+ indicates complementarity)**
	Category	**Specific variable**	
Dependent variable is privately funded or performed research (BERD/GDP)	**Direct Assistance for BERD**	Government funded BERD /GDP	+ Guellec & van Pottelsberghe (2003)
			0 (+ in only some models) Falk (2005 & 2006)
			+ Czarnitzki et al (2004)
			0 (0 in 15 countries, + in 5, - in 2) von Tunzelmann & Martin (1998), cited by David, Hall & Toole (2000)
			+ Czarnitzki & Ebersberger (draft 2006)
		(Government funded + privately funded BERD) /privately funded BERD	+ Wolff & Reinthaler (2005)
		Government funded BERD /privately funded BERD	0 Bassanini & Ernst (2002)
	Publicly performed R&D	R&D undertaken in university labs /GDP	- Wolff & Reinthaler (2005)
			0 Guellec & van Pottelsberghe (2003)
			+ Czarnitzki et al (2004)
			+ Falk (2006)
		R&D undertaken in government labs /GDP	0 Wolff & Reinthaler (2005)
			- Guellec & van Pottelsberghe (2003)
			+ Czarnitzki et al (2004)
			0 (+ in only some models) Falk (2005)
		The sum of the above two variables	+ Ryan & Ridge (1999)
			+ Czarnitzki et al (2004)

+ indicates a positive coefficient, - indicates negative, and 0 indicates a lack of robust statistical insignificance. Source: Adapted from Falk (2006a), and expanded. All studies use country level data, except Czarnitzki et al (2004) who use industry level data and Czarnitzki & Ebersberger (2006) who use firm level data. Table 13 presents these findings in greater detail. Source: compiled by the authors.

Table 13: Single-Country Studies of Effects of Direct Assistance on Input, Output and Behavioural Additionality, 1995-2006

Notes: 'Input additionality' refers to effects of direct assistance on e.g. private R&D spending and hiring decisions; 'output additionality' refers to effects on e.g. productivity, spillovers and patenting; and 'behavioural additionality' refers to effects on e.g. collaboration and the type of research undertaken. The table emphasizes studies that control for selection bias, examine crowding out or in (input additionality), and identify particularly sensitive categories of firms. "Some evidence of" indicates suggestive but not robustly significant evidence. The last two entries on Canadian indirect subsidies are included for comparative purposes. A "Yes" for "controls for selection bias" indicates the study made some attempt to control for some for selection, endogeneity or simultaneity bias, although it may not have been fully successful. RJV stands for Research Joint Venture. Source: Compiled by the authors.

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
Austria 2004 Manuf. firms	Falk (2006b)	No	Complementary. Also finds some evidence that subsidies encourage riskier, longer term & collaborative research projects.	Complementarity not influenced by firm size and tech level. Some evidence that: firms founded within 5 years conduct longer term, larger research projects; firms with over 250 employees conduct longer term, riskier, more basic research; firms that also received past subsidies conduct have greater complementarity and collaborate more.
Austria 1996-2002 Firms	Falk (2004a)	No	Direct BERD subsidies have a much smaller positive impact than privately funded BERD on subsidy recipients' labour productivity growth	
Austria 1996-2002 Regular R&D performing firms	Falk (2004b)	No	Finds subsidies have a statistically significant but very tiny impact on R&D employment. This can be interpreted as a rejection of full crowding out.	
Austria 1998-2000 Firms	Leo (2003)	Yes	Rejects full crowding out (used receipt not level of subsidy so cannot distinguish partial crowding out and complementarity). Also finds small positive impact of subsidy on employment & sales.	
Austria 1997-2002 Firms	Streicher et al (2004), Schibany et al (2004)	No	"Most probably" complementary	Greater complementarity for firms with under 10 or over 250 employees, and some evidence of greater effect for firms that had not conducted R&D for at least 2 years
Austria 1998-2000 Firms	Garcia & Mohnen (2004)	Yes	Rejects full crowding out for direct BERD subsidies given by national government (used receipt not level of subsidy so cannot distinguish partial crowding out and complementarity), but cannot reject full crowding out for direct BERD subsidies given by EU. Finds national subsidies have a positive effect on innovative sales.	
Flanders (Belgium) 1998-2000	Aerts & Czarnitzki (2005)	Yes	Complementary	
Flanders (Belgium) 1997, 15 largest R&D performers	Janssens & Suetens (2001)	No (survey)	Crowding out	
Flanders (Belgium) 1992-97, R&D performing firms	Meeusen & Janssens (2001)	No	Complementary	Complementarity for small and medium size firms (under 250 employees), insignificant or weaker effect on large firms
Flanders (Belgium) 1992-99, Large firms that regularly apply for R&D subsidies	Suetens (2002)	Yes	Partial or full crowding out, with BERD proxied by R&D employment	
Denmark 1999,2001 Manuf & Service firms	Kaiser (2004)	Yes	Insignificant	
Denmark Manuf. Industries 1974-95	Sorensen et al (2003)	No	Complementary. Also finds a robustly positive but insignificant long run impact of subsidies on TFP.	

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
E.U. 1998-2000, Firms <500 employees (We include this multi-country study in the table because it uses firm-level data and has implications for firm size)	Czarnitzki & Ebersberger (draft 2006)	Yes	Complementary. Also finds the subsidy improves equity in the distribution of private research spending by firm size.	Complementarity is only significant for firms of a size in the range of the 40% to 95% quantiles. I.e., small and very large firms not affected.
E.U. 1987-99 13 countries, industry level analysis as well	Czarnitzki et al (2004, ch. 2.3)	No, industry level	Complementary in regression with 13 pooled E.U. countries. In regressions for individual countries, finds complementarity for Austria, Denmark, Finland, France, Germany, Ireland, Portugal, Spain, & Sweden; no effect for Italy; insignificant complementary effect for U.K & U.S. When pooling the same industries across different countries, finds complementarity in 16 of 18 industries.	Higher elasticity of privately funded BERD to subsidies in higher tech industries. Since assumed constant elasticity, this implies incrementality ratio is inversely related to industries' degree of subsidization. Lower tech industries tended to be less subsidized, implying greater complementarity there in this framework.
E.U. 1985-96 Manuf. firms members & non-members of subsidized RJVs	Benfratello & Sembenelli (2002)	No	Membership in EUREKA sponsored consortia was correlated with increased labour productivity, total factor productivity, and price-cost margin; no effect from Framework Program sponsored consortia.	
E.U. 1992-96 Member and non-member firms of subsidized RJVs in 2 industries	Cusmano (2001)	Yes	Membership in consortia (subsidized by Framework Programs or the EUREKA Program) increases patenting in medical and biotechnology industry, but not in ICT industry.	Membership has negative effect on patenting of small firms, some evidence of positive effect on medium and large size firms.
Finland & West Germany 1996 & 2000 manuf & bus. services firms	Czarnitzki, Ebersberger & Fier (draft 2006)	Yes	Direct BERD subsidies significantly increase the probability of patenting of Finnish firm recipients, effect is not significant for West Germany	Some evidence that subsidies for collaborative research stimulate more patenting than subsidies for individual research
Finland & Germany 1994-2000 firms	Ebersberger (2005)	Yes	Complementary (only examines Finland) and greater probability of patenting (examines both Finland & Germany). Confirms that the induced BERD input triggers the increased patenting.	Smaller firms have greater complementarity. Some evidence of greater complementarity in high tech. Patenting effect is stronger when subsidy encourages collaboration between firms.
Finland 1996-2000 firms	Ebersberger (2004a), Ebersberger & Lehtoranta (2005)	Yes	Subsidized firms have higher employment growth in long run but not short run, and higher average annual patenting	
Finland 1996-98 Firms	Ebersberger (2004b)	Yes	Finish BERD subsidies (which promote collaboration) reduce the probability of a recipient merging, and, to a less extent, reduces probability of exiting.	
Finland 2001 SMEs (avg. 17 employees)	Hyytinen & Toivanen (2003)	Yes	Implication on average is not clear from the study, since it does not explicitly address crowding out	Subsidies have a greater stimulatory effect on BERD and on sales growth on firms in industries that are more reliant on external financing
Finland 1999-2002 Firms & projects	Takalo et al (2005)	Yes	Finds positive return on investment from direct subsidies, but study does not compare with returns to privately financed research.	Marginal profitability of R&D projects is larger for larger firms, but is correlated with higher firm application costs that discourage applying
Finland 1996-2002 Tech firms	Ali-Yrkkö (2005a)	Yes	Complementary	Greater complementarity for large firms. Effect of indebtedness is insignificant.
Finland 1997-2002	Ali-Yrkkö (2005b)	Yes	Subsidies increase recipients' R&D employment, but not non-R&D employment, at least in short run	Firm size did not affect the impact of subsidies on R&D employment
Finland 1996-2001 Metal & electronics firms	Ali-Yrkkö & Pajarinen (2003)	Yes	Complementary	
Finland, Plants	Lehto (2002)	Yes	Rejects crowding out	

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
Finland 1975-93 Manuf. industries	Niininen (2000)	No, Industry level	Findings are insignificant, but imply that publicly financed BERD increases industry costs while privately funded BERD decreases industry costs, and that publicly funded BERD increases productivity in more industries than does privately funded BERD	Effects not significant, but vary by industry
Finland 1989-93 Firms	Toivanen & Niininen (2000)	Unclear from second-ary sources	Crowding out on average, according to Garcia-Quevedo (2004) who cites an earlier 1998 working paper. We could not find a secondary for the 2000 version that comments on the average effect.	Secondary sources for the 2000 version: Loof et al (2005) say finds no effect for large, complementary effect for small firms. Ali-Yrkkö (2005a) says finds complementary effect for medium-cash flow firms, not others. Ebersberger (2005) says finds greatest complementarity for modestly credit-constrained firms.
France 1985-1997 R&D performing firms	Duguet (2004)	Yes	Complementary	Some evidence that effect increases with size, R&D intensity, financial constraint, and receipt of past subsidies
France Firms	Favre et al (2002)		Rejects full crowding out from domestic French BERD subsidies but not European BERD subsidies. Whether the study distinguished partial crowding out from complementarity cannot be determined from citation by Hanel (2003). Also finds domestic subsidies encourage international cooperation.	
Germany 1992-2000 R&D performing firms	Czarnitzki & Hussinger (2004)	Yes	Complementary. Also finds that the induced BERD leads to more patenting.	
Germany 1994-98 Firms<500 employees	Czarnitzki (2006)	No	Rejects full crowding out	
Germany 1994-2000 firms	Czarnitzki & Licht (2006)	Yes	Complementary. More complementary in East than West German firms.	
West Germany 1979-93 Manuf. industries	Bonte (2004)	No, industry level	Finds that direct BERD subsidies in Germany generate positive but insignificant inter-industry spillovers, while privately funded BERD generates positive & significant inter-industry spillovers	The potential for generating inter-industry spillovers varies depending on the particular subsidy receiving industry
Germany 1994-1998 service firms	Czarnitzki & Fier (2001)	No	Complementary	
Germany 1996,98	Czarnitzki & Fier (2002)	Yes	Rejects null hypotheses of full crowding out; methodology cannot distinguish partial crowding out and complementarity	
Germany 1992-2000	Czarnitzki & Fier (2003)	Yes	Firms in publicly financed consortia are more likely to patent than firms in non-publicly financed consortia	Firms in consortia are more likely to patent than firms not in consortia
East & West Germany 1997-2000 Firms	Hujer & Radic (2005)	Yes	Subsidy has insignificant impact on recipients' probability to introduce a new product or service or to improve an existing one (small positive effect when using ordinary matching model, insignificance when further controlled for unobservables.) Some evidence of a small positive impact in East Germany.	Some evidence of a small positive impact for SMEs.
Germany 1992-2000 Firms	Fier, Heger & Hussinger (2005)	Yes	Complementary	
Germany 1992-2000 Manuf. firms	Licht & Stadler (2003)	Yes	Rejects full crowding out (more than that cannot be determined from secondary source Hujer & Radic, 2005)	

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
East Germany 1994,96,98 R&D performing manuf. firms	Almus & Czarnitzki (2003)	Yes	Rejects full crowding out (study examines effect of receipt of a subsidy, not level of subsidy, so cannot determine between partial crowding out and complementarity)	
Germany 1992-2000 R&D performing firms	Hussinger (2003)	Yes	Complementary	
G7 countries 1974-90 Country-level data	Capron & Van Pottelsberghe (1997)	No, country level	Crowding out for Canada, France, & Italy; Insignificant for U.S., Germany & Japan; Complementary for U.K.	Some evidence of greater complementarity in medium tech industries
Israel 1990-95 R&D performing manuf. firms	Lach (2002)	Yes	Insignificant (significant crowding out in short run, outweighed by larger but insignificant complementarity in longer run)	Complementary for small firms in long run (outweighs short run substitution). Some evidence of crowding out for large firms.
Japan	Koga (2003)	Unsure, only abstract was accessed	Complementary	Effect is stronger for more mature firms
Japan 1980-92 Firms & consortia	Branstetter & Sakakibara (2002)	Yes	Firms in subsidized consortia patent modestly more than non-members, but no evidence that the level of the subsidy matters	Consortia patent more when they focus on basic research, and when members' earlier patents are in similar areas
Japan 1969-94 Firms & consortia	Sakakibara (2001)	Yes	Crowding out. Members of subsidized consortia reduce BERD in response to higher subsidies.	Consortia members spend more on research when they are not competitors and when their earlier patents are not in similar areas. Holding subsidy level constant, membership leads to higher BERD.
Norway 1996 Subsidized firms	Nesset (2001)	Yes	Crowding out (not clear from Braein et al 2002 whether partial or full). Increasing the level of subsidy per employee decreases privately financed BERD, and does not make a non-performer more likely to become a performer.	Firms that already perform R&D are more likely than non-R&D performers to be induced by subsidies to increase their privately financed BERD
Norway	Braein et al (2002)	No (survey)	Complementary	
Norway	Rye (2002)	No (discusses several surveys)		Greater complementary for small and medium sized firms, and for higher risk projects farther from market
Norway 1982-95 Firms	Klette & Moen (1998)	No	Complementary, according to Garcia-Quevedo (2004)	
Spain 1988 Manuf firms	Busom (2000)	Yes	Complementary on average, but cannot reject full crowding out for 30% of firms, and partial crowding out may be important for many firms. Similar result whether dependent variable is BERD or research employment.	
Spain 1989-98 Industries	Callejon & Garcia-Quevedo (2005)	N/A since industry-level	Complementary	Complementary in medium-high and medium-low tech, insignificant in high and low tech industries.
Spain 1990-99 Manuf firms	Gonzalez, Jaumandreu & Pazo (2005a)	Yes	Rejects crowding out, finds modest complementarity on average	Greater complementarity for firms with under 200 employees and for firms that do not already perform R&D, but these are disproportionately non-recipients, leading to low average effect. Finds 2 types of complementarity: induce R&D performers to perform more, and induce non-performers to perform

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
Spain 1990-99 Manuf firms	Gonzalez & Pazo (2005b)	Yes	Rejects crowding out, but no significant complementarity either	Complementary for firms with under 200 employees & low & medium low tech firms, insignificant for others
Spain Firms	Heijs (2003)		Some evidence that firms with crowding out achieve fewer of their technical and commercial goals than firms with complementarity	
Spain 1998-2000 Firms	Herrera & Heijs (2004)	Yes	Partial crowding out (subsidies increased total BERD, implying a rejection of full crowding out, but by less than the size of the subsidy)	Partial crowding out, present for all firm sizes, was slightly less of a problem for firms with under 500 employees than firms with more
Spain 1998-2000 Firms	Herrera & Nieto (2006)	Yes	Rejects full crowding out (implicit since firms which receive a subsidy have greater R&D intensity), but unable to determine between partial crowding out and complementarity since the study uses subsidy receipt rather than level	Some evidence of a larger effect in regions where firms operate in emerging markets and export technology.
Sweden, Impact in 2003 of small public firms subsidized 1994-97	Bager-Sjogren & Loof (2005)	No	Some evidence that conditional loans (repayable if generate sales), a form of direct BERD subsidy, have an insignificant or negative effect on firm survival, sales, productivity, employment & attraction of equity financing	Some evidence of positive effects for recipients established within 3 years of receiving subsidy
Sweden 1998-2000 R&D performing manuf. & services firms	Loof & Heshmati (2005)	Yes	Rejects full crowding (subsidy receipt has a positive impact on total BERD per employee, cannot determine between partial crowding out and complementarity since study does not use subsidy level)	Some weak evidence of greater impact of subsidies on firms with under 50 employees than firms with more
Sweden 1995-2001 Firms <250 employees	Bager-Sjogren & Loof (2003)	Yes	Subsidy recipients have higher economic performance than non-recipients	
Sweden 1982-90 Competing firms	Folster & Trofimov (1996), Folster (1995b)	Unclear from secondary source	When a firm in a group of competing firms receives a subsidy, full crowding out can be rejected for the recipient firm, but more than full crowding out occurs for the group as a whole, according to Capron & van Pottelsberghe (1997). Implies that any BERD induced in the recipient may be outweighed by crowding out of competitors' BERD.	
Sweden Firms	Folster (1995a)	Unclear from secondary source	According to Martin & Scott (1998), finds some evidence that: BERD subsidies for collaborative research, where the form of collaboration is discretionary, do not encourage collaboration, and do not induce more BERD than normal BERD subsidies do; and BERD subsidies that require a results-sharing agreement encourage collaboration but discourage BERD.	
Turkey 1993-2000 Manuf. firms	Ucdogruk (2005)	No	Subsidized firms hire more researchers, but fewer technical and support staff	
U.K. 1993-2000 Manuf. industries	Becker & Hall (2004)	N/A since industry-level	Rejection of full crowding out (implied by finding that increasing the portion of industry BERD that is subsidized increases total industry BERD), insufficient info to determine between partial crowding out and complementarity	Complementary in low tech, insignificant in medium & high tech industries
U.S. 1985-98 Research Joint Venture (RJV) filings	Link et al (2002 & 2005)		Finds some evidence that a decrease in funding for the U.S. ATP subsidy for R&D, especially collaborative R&D, may have lead to a decrease in collaboration	
U.S. Manuf. firms	Billings et al (2004)	Unsure, only abstract accessed	At least in chemical research, subsidy recipients have less output per dollar of R&D than non-recipients	
U.K. 1993-2000 Manuf. industries	Becker & Pain (2003)	N/A since industry-level	Rejection of full crowding out (implied by finding that increasing the portion of industry BERD that is subsidized increases total industry BERD), but, given sample means, the range of estimates covers both partial crowding out and complementarity	

Country & data	Study	Controls selection bias	Average effect of the level of direct assistance on the level of privately financed BERD, unless otherwise stated	Factors that enhance the effect (possible implications for targeting direct assistance)
U.S. Non-farm bus. sector	Bonte (2003a)	Unsure, only abstract accessed	Finds that privately and publicly funded BERD have a similar impact on productivity	
U.S. 1985-95 Large firms & consortia	Sakakibara & Branstetter (2003)	No (somewhat through fixed effects)	Membership in subsidized consortia is associated with more patenting	Effect of consortia membership on patenting is larger when members have earlier patents in similar areas. Some evidence that effect is greater for large firms.
U.S. 1998 Firms that applied for ATP subsidy	Feldman & Kelley (2003)	No, (survey)	Most failed applicants conducted a scaled down version of the proposed project (suggestive that can rule out full crowding out on average), though a few continued with the same or expanded version of the project. Subsidy recipients were more successful than non-recipients at obtaining subsequent funding from other sources.	
U.S. 1958-91 11 manuf. industries	Saal (2001b)	N/A, industry level	Insignificant (found some evidence of crowding out, but only significant in one of several regressions)	
U.S. 1985 & 1995	Lerner (1999)	No (Wallsten 2000)	Subsidy increases sales growth and employment growth	Only firms in ZIP codes with venture capital activity were influenced, especially high tech firms
U.S. 1990-92 Small (avg about 40 employees) High Tech firms	Wallsten (2000)	Yes	Cannot reject full crowding out of private R&D effort, regardless whether it is measured as BERD or employment	
U.S. 1956-88 Manuf. industries	Mamuneas & Nadiri (1996)	No, industry level	In recipient industries, direct BERD subsidies are complementary with privately financed BERD, and reduce costs. Also finds that the sum of direct BERD subsidies and R&D performed by government agents and non-profits crowds out privately financed BERD in non-recipient industries, and reduces costs. The total effect of direct BERD subsidies and R&D performed by government agents and non-profits on the manufacturing sector is crowding out, but this does not allow us to determine the net effect of direct BERD subsidies in particular.	Again, the total effect of direct BERD subsidies is not isolated, but the total effect of all publicly financed or performed research is found to be more than full crowding out in low R&D intensive industries, and partial crowding out in high tech industries
U.S. 1970–1993 80 member and non-member firms of SEMATECH research consortium	Irwin & Klenow (1996)	No (Klette et al 2000)	More than full crowding out (can be interpreted as a success if consortium membership reduced unnecessary duplication of R&D effort). Also finds that membership in the subsidized consortium led to faster sales growth, but did not affect physical investment, labour productivity growth, or the return on assets or sales.	
Canada 1999 Firms	Czarnitzki, Hanel & Rosa (2005)	Yes	This study deals with tax credits, which are found to increase the probability of performing at least some R&D and of introducing & selling innovative or improved products, but do not significantly affect profitability, productivity or market share, at least in the short run	
Canada 1999 Firms	Hanel (2003)	Yes	Tax credits improve the likelihood of introducing an innovation, but subsidies do not. Subsidies improve the portion of sales that are innovative, tax credits do not.	Tax credit users are more likely to introduce an innovation if they collaborate with other firms or public labs

Annex 4: Comparison with Other Evaluations

Table 14 compares this 2006 evaluation with relevant other evaluations that we are aware of that go beyond merely estimating the sensitivity of R&D to tax incentives and perform a more thorough cost benefit analysis.[1] Three are official government publications: Finance Canada and Revenue Canada (1997), Australian Bureau of Industry Economics (1993), and Australian Industry Commission (1995). Another two were written by Australian government employees: Lattimore (1997), included in an OECD publication, and Yoon & Lee (2004), a draft conference paper. The Dutch evaluation, Cornet (2001), is unofficial.[2]

The three most important exogenous parameters used in our model are included in the table: the Marginal Excess Burden of taxes used to finance the subsidy, the spillover rate of return to investment in R&D, and the incrementality ratio. Together with the subsidy rate, the tax rate, and administration and compliance costs these parameters are sufficient to derive the net welfare gain per dollar of tax expenditure reported in the results section of the table. Certain parameters reported or used by other evaluations are also listed. To increase comparability between studies, blanks were filled in as much as possible, such that in some cases an estimate is shown even if it was not used in the welfare analysis of the study. The table indicates values that are not used by a given study but are implied (calculated by us) or reported.

This table does not provide all of the information necessary to comprehensively compare the studies, since some of the less important or more obscure parameters and assumptions are omitted. GE models in particular depend upon numerous assumptions. There is also information missing on the PE models. For example, the table does not reveal that this present study is unusual in that it takes into account the fact that the MEB applies to an effective tax expenditure that is lower than the nominal amount of tax credits since R&D spillovers generate some tax revenue.

[1] Several evaluations are intentionally omitted from the table. Bloom et al (2005) is a stylized U.S. policy simulation; Lattimore (1996) evaluates a defunct aspect of the Australian incentive which applied to research syndicates, and Russo (2004) is not relevant here because it is purely theoretical, not applied.
[2] The Dutch system is summarized thoroughly in van Pottelsberghe, Nysten & Megally (2003).

BIE (1993) notes a survey-based estimate suggesting that 17% of Australian R&D would not have taken place in the absence of the tax incentive. This implies that at least 83% of the R&D being subsidized would have taken place regardless of the tax incentive. BIE calls this latter the 'transfer' component of the tax expenditure, and assumes that a portion (BIE estimates 20%) of this transfer leaks out of the economy as payments to non-resident shareholders. Lattimore (1997) and Yoon & Lee (2004) also take this approach, however, for the reasons briefly canvassed in section 5, we do not.

Finally, it is important to keep in mind the benchmark against which these evaluations are measuring the welfare impact of the R&D subsidies. In the Canadian studies, the tax credits are benchmarked against a zero credit rate. In the Australian studies, the super depreciation rates or 'tax allowance' above 100% are benchmarked against depreciation rates of 100%, although AIC (1995) acknowledges that even a 100% rate is more than sufficient to compensate for the true economic rate of depreciation. van Pottelsberghe, Nysten & Megally (2003) write that, "given the fact that it is such a weak stimuli and such a widespread measure, full depreciation of current R&D expenditure is not considered as an important measure", but they acknowledge that accelerated depreciation for some capital items may be more important.

Finance and Revenue Canada (1997) and BIE (1993) estimated administration and compliance costs but did not include them in their welfare model. As the Auditor General of Canada and AIC (1995) point out, if those costs had been taken into consideration, the small positive welfare estimates would have become slightly negative.

Table 14: Comparison of Evaluations of R&D Tax Incentives

Study	This study Parsons & Phillips (2007)	Finance Canada & Revenue Canada (1997)	AIC (1995)	BIE (1993)	Lattimore (1997)	Yoon & Lee (draft 2004)	Cornet (2001)
Model	Static PE	Static CGE	Static CGE	Static PE	Static PE	Static PE	Static PE
Country & base year	Canada 2004	Canada 1992	Australia 1990/91	Australia 1990/91	Australia around 1996	Australia 2003/04	Netherlands 1997
R&D tax incentive evaluated	20-35% tax credit	20-35% tax credit	150% deduction	150% deduction[1]	125% post / 150% pre-1996 deduction[1]	125% deduction[1]	13-40% tax credit on R&D wages
Effective credit rate (TE/ES), or subsidy rate[2]	20.1% credit rate,[3] subsidy rate is 4.3[4] percentage point reduction R&D user cost	18% credit rate implied, not used	Subsidy rate: 19.5 cents per dollar of eligible spending, nominal, not used, implied 12.7% credit rate	Subsidy rate 16.5 cents per dollar of eligible spending, eff.[5] Implied 16.8% credit rate	7.1% / 14.1% credit rate[6]	Subsidy rate 7.5 cents per dollar of eligible spending, nom., not used,[7] implied 4.9% credit rate, not used	8% credit rate reported, not used[8]
Marginal excess burden of taxation (MEB)	0.27[9]	Endogenous[10]	Endogenous[11]	0.325 (0.15 to 0.50)[12]	0.275 (.15 to .4)[13]	0.30[14] (0.2 to 0.4)	0.25 (.15 to .35)
Spillover rate of return on R&D stock	56% total spillover[15]	10% inter-industry spillover, lower bound[16]	0% to 11% inter-industry spillover[17]	78% (66% to 90%) total spillover[18]	70% total spillover[19]	80% (30% to 130%) total spillover[20]	40% (20% to 60%) social return[21]
Incrementality ratio (I=ΔR&D/ΔTE)[22] or Inducement rate (ΔR&D/ES)[23]	0.86 incrementality ratio[24]	1.38 incrementality ratio[25]	15% inducement rate,[26] implied 1.2 incrementality ratio	0.8 (0.6 to 1.0)[27]	8.40% / 13.35%[28] inducement rate, implies 1.19 / 0.95 incrementality ratio[29]	0.7 (0.5 to 0.9) incrementality ratio[30]	0.75 (0.5 to 1.0) incrementality ratio[31]
Tax rate	30% economy-wide[32]		39% statutory (nom.) corporate income tax[33]	39% statutory (nom.) corporate income tax	36% statutory (nom.) corporate income tax	30 statutory (nom.) corporate income tax	Not reported or used
Years to adjust to policy change	Not used	Equilibrium characterized as "longer term"	10 year "solution horizon"[34]	Not used	Not used	Not used	Not used, except social returns discounted by assumed 2 year lag
Discount rate or private rate of return on R&D[35]	12% discount[36]		Not used	8% discount[37]	8% discount[38]	Not used[39]	6.5% discount (6% to 7%)[40]
Depreciation rate for R&D stock	10%[41]	10%[42]	10%[43]		Not used	Not used	5% (0-10%)[44]

Study	This study Parsons & Phillips (2007)	Finance Canada & Revenue Canada (1997)	AIC (1995)	BIE (1993)	Lattimore (1997)	Yoon & Lee (draft 2004)	Cornet (2001)
Share of transfer component (subsidy of non-induced R&D) that leaks overseas	Not used	Not used[45]	Not used	20% (10% to 30%[46]	17.6%[47]	20%[48]	Not used
Business compliance cost / TE	7.9% of tax credits[49]	5.5% to 15% reported, not used[50]	Assumed low, not used[51]	12% to 24% implied, not used[52]	7.1% / 3.5% implied[53]	12% implied[54]	5%[55]
Government admin cost, annual	2% of TE[56]	Not used	0.4% of TE, not used[51]	Not used, reported 0.6% of TE[57]	1.8% / 0.9% of TE[58]	3.6% of TE[59]	3% of TE[60]
Net welfare gain per $ of tax expenditure	+11 cents	+1.6 to +4.4 cents lower bound[61]	+10.3 cents[62]	+10 cents (-5 to +25)[63]	+31 cents / +19 cents[64]	Ratio of benefits to costs of 0.7 to 1.3[65]	+13.8% (-3.9 to +32.4%) internal rate of return

Source: Compiled by the authors.

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1 The 150% deduction was reduced to 125% in 1996. Lattimore (1997) conducts an evaluation at both levels.

2 For the Australian studies, the nominal subsidy rate is the statutory corporate income tax rate times the amount of the deduction which exceeds 100%, and is interpreted as cents of subsidy per dollar of eligible spending, or "the theoretical subsidy equivalent per unit of eligible industrial R&D" (AIC, 1995, p. QD16). AIC notes that this is on a post tax basis, and that it can be converted to a pre-tax basis by dividing by 1 minus the corporate income tax rate, p. QD16. The effective subsidy may differ from the nominal subsidy, for example due to clawbacks and delayed realization.

3 Five year average from 2000 to 2004. See Annex 1.

4 Five year average from 2000 to 2004. This is in after tax terms. See Annex 1.

5 Four year average of fiscal years 1988/89 to 1991/92, taking into account realization lags (probability distribution estimated from 1992 survey), clawback effect (from dividend imputation), and discount rate, p. 66. Used to estimate effective tax expenditure. The nominal subsidy rate is 19.5 page 58.

6 Page 116.

7 The nominal subsidy rate is the company tax rate (30%) times the superallowance (25%).

8 In 2001.

9 From a dynamic Canadian CGE model presented in a 2004 Finance working paper by Baylor & Beauséjour.

10 As a static GE model, which included personal, corporate, payroll and commodity taxes, but excluded the dynamic impact on domestic saving, the model likely understated the MEB. Two financing scenarios were used: flat tax (raising taxes by the same number of percentage points) and ad valorem (raising taxes by the same percentage), reflected in the range of estimates reported for net welfare gain per dollar of tax expenditure.

11 The authors refer to BIE (1993c) for more details.

12 Range, page 239, based on literature review by BIE (1992).

[13] Lattimore cites on page 111 the assumption used by BIE (1993), and adjusts it down given a lower and more recent Australian estimate of Campbell & Bond (1997).

[14] Assumed to be reasonable, citing BIE (1993) and Lattimore (1997).

[15] Derived from the median of 9 Can. estimates published 1988-2004 in gross terms, which were converted to net rates by subtracting an assumed depreciation rate.

[16] To be conservative, the lowest average spillover rate, weighted by industry contribution to gross output, was selected from a sample of four studies including and reported by Bernstein (1994). The lowest rate came from Bernstein (1988). Interpreted by the model as meaning that a $1 investment in R&D by one industry results in a 10 cent reduction in production costs in other industries.

[17] The elasticity of TFP with respect to other industries' R&D was estimated for four sectors, ranging from 0 to 0.109. The elasticities for the 18 industries included in the model were assumed to be equal to their sector estimates. See section QB.

[18] Range derived using the average gross private return to induced R&D and the average spillover to private returns (SPR) ratio, p. 235. It is apparent that BIE assumed an SPR of near 1. Using SPR implies assuming that spillovers are a constant portion of the private. This is commented on in AIC (1995, p. 538).

[19] Lattimore, page 110, chooses this rate as more conservative than the BIE (1993) assumption and central within the range of international estimates.

[20] The midpoint is 80%, but authors used a large range (from lit review) for sensitivity analysis due to ambiguity.

[21] Cornet calculates net welfare by subtracting social costs from social benefits, without calculating spillovers. He cites a social rate range of 25% to 100% from the literature, which he adjusts downward since subsidized projects are not necessarily those with the highest social return, and since the program requires eligible R&D to be new to the firm but not necessarily new to society.

[22] As defined here, the incrementality ratio is also equal to the inducement rate over the effective credit rate.

[23] Lattimore (1997) and AIC (1995) use this definition of the inducement rate. Others have used the term to refer to the incrementality ratio.

[24] Median of 6 Canadian estimates published 1996-2004, in Table 1. Two of the incrementality ratios were estimated directly, the others we adjusted to apply a consistent method of converting from price elasticity.

[25] 1994 survey of 501 recipients of the SR&ED tax credit or tax deduction, p. 54, conducted by ABT & Associates.

[26] Chosen from the range of 11% to 20% estimated by BIE (1993). Mentioned AIC pages QC9 and QC15.

[27] Range, p. 238, derived from the estimated percentage of R&D that is induced, which was taken from a 1992 survey of 880 firms. Specifically, 0.74 to 1.17 for Australian firms, and 0.37 to 0.78 for foreign firms (also eligible for the tax incentive), where lower bounds correspond to projects which respondents reported to be 'critically' affected by the tax incentive.

[28] Lattimore, page 109, uses the mean of the range of estimates derived from the BIE 1992 survey.

[29] Reported on page 116, Lattimore derived these from his assumed inducement rates.

[30] Range assumed reasonable by the authors, although their five point estimates derived from their survey ranged from 0.57 to 2.06.

[31] Cites much higher Dutch estimates by Bureau Bartels (1998) and van den Hove et al (1998), chooses a lower range since they may have methodological problems, there may be re-labelling of non-R&D, and cites evidence that R&D spending partially reflects higher wages (Marey & Borghans 2000, Goolsbee 1998, Trajtenberg 2000).

[32] The economy-wide rate (see section 4.1), revenue from all levels of government over nominal GDP, is applied to the returns to R&D.
[33] Mentioned appendix page QD16, used to calculate nominal subsidy rate. Page QC15 notes that several tax rates were modelled.
[34] The model was designed to adjust to a new equilibrium over a solution horizon of 10 years, appendix pages QC5 and QC8.
[35] A discount rate is often used to convert a nominal subsidy rate into an effective subsidy rate, by taking into account realization lags.
[36] Discount rate of 12% is used to find present value of tax credit carryforwards. Taken from Bernstein's (1988) estimate of an 11.62% private rate of return to R&D net of depreciation (the only firm level Can. estimate). The private return, grossed up by adding an assumed 10% rate of depreciation to yield 21.6%, was used to derive spillover rates from social rates in the literature. This gross private rate was also assumed equivalent to the user cost of R&D in order to calculate the subsidy rate.
[37] Discount rate is sum of 3% assumed inflation (near average from 1990/91 to 1991/92) and 5% assumed real discount rate – the lower bound of estimates used in cost benefit analyses surveyed by BIE (1992, p. 62). BIE (1993, p. 235), assumes average gross private return to induced R&D i to be less than one but greater than one minus the percentage reduction in the after tax cost of R&D caused by the tax concession (1 minus 27%). 86.5% is the midpoint of 73% and 100%. Lattimore (1997, p. 130) notes that BIE (1993) "did not subtract the difference between private rates of return on induced R&D and their opportunity rate of return from the net benefit."
[38] The discount rate, page 116, is not explained. Lattimore, page 114, assumes that private returns to R&D are the same as on other assets.
[39] Based on survey responses which Yoon & Lee felt were likely overstated, they estimated an upper bound on the private return of 35%.
[40] Assumes a social rate of time preference of 4%, plus a risk premium of 2% to 3%.
[41] The rate assumed by most Canadian and other empirical R&D studies. Used here to convert private rate from gross to net of depreciation.
[42] The Bernstein (1998) study used as the source of the spillover rate assumed a depreciation rate of 10% to convert rates of return from gross to net of depreciation.
[43] Assumed in order to calculate the growth rate of knowledge stocks, appendix page QC5.
[44] Cornet cites this range as the typical assumptions by researchers, terms it the 'social' depreciation rate, and uses it to calculate social benefits.
[45] Page 34 notes that in 1992, 94% of claimants were over 50% owned by Canadian residents, accounting for 78% of the value of claims.
[46] 20% estimate based on assumptions on page 237, sensitivity range reported page 240.
[47] From p. 112, this is the 22% share of R&D transfers (subsidy of non-induced R&D) attributed to foreigners by ABS statistics, reduced by an ad hoc assumption that 20% is clawed back through means such as withholding taxes.
[48] From their survey, 30% of R&D firms were foreign owned, weighted by R&D intensity. They assumed that "33% of foreign profits accrue to Australia (through taxes and other transfers)." "In other words, similar to Lattimore, we estimate that the private Australian benefit is equal to 80% of the total private benefit." (which they assumed to be equal to the tax expenditure, by assuming no market failure in private investment in R&D that is optimal in private terms).
[49] Weighted average of ongoing compliance costs for small, medium & large claims, based on a 1994 survey conducted for Finance Canada & Revenue Canada (1997), weighted by the 2003 distribution of claim sizes according to Cortax data from CRA. See section 2.4.
[50] Based on a 1994 survey, compliance costs as a portion of credits claimed are 5.5% for large claims over $500,000, 10% for medium claims, and 15% for small claims under $100,000. For first time SR&ED claims these are 8%, 13% and 21% respectively, page 78. The application form for small claims has been streamlined since this survey was undertaken.

[51] Page 652 notes the IR&D board estimate of administration costs "for recent years" (the AUD 1.2 million is implied), and the assumption that compliance costs are low due to "little need for administrative assessment".
[52] Not included in welfare analysis, but estimated from 1992 BIE survey, as a fraction of ES rather than TE, at 8% in the first year and 2% to 4% in subsequent years, p. 126. However, Lattimore (1997, p. 112) interprets the survey as revealing compliance costs as 1.6% to 3% of ES.
[53] Lattimore, p. 112, assumes 0.5% of eligible spending, judging the survey-based estimate of BIE (1993) to "not gel with common sense". On page 116 he translates this into AUD 12.0 million for the 125% incentive and AUD 12.7 million for the 150% incentive.
[54] For all tax concessions, estimate was 1.0% of eligible business R&D expenditure, which is a weighted average of 2.2% for small and 0.8% for large firms, an average of AUD 22,000, from survey by Yoon & Lee. They attribute 58.3% of the compliance costs to the 125% deduction portion of the tax concession. This implies compliance costs of 12% of tax expenditure, or a total pf AUD 35 million.
[55] How Cornet arrived at this estimate is unclear from the English summary.
[56] $40.9 million reported by CRA for fiscal year 2004/05. If employee benefits are included, this amount increases about 20%. See section 2.4, where it is expressed as % of tax credits rather than tax expenditure.
[57] In the 1991/92 fiscal year in 1990/91 constant prices, BIE estimates from data from DITARD and ATO, p. 68.
[58] Lattimore, page 116, reports AUD 3.0 million for the 125% and AUD 3.2 million for the 150% deduction. The % of TE estimates are implied.
[59] Australian National Audit Office (2003). The % estimate is implied.
[60] Cornet (2001a) reports 3% of tax expenditure, and (2001b) reports 18.4 million guilder in 1997: 11.1 million for Senter and 7.3 million for the Tax and Customs Administration, figures from the Minister for Economic Affairs, 1999. Using NLG 1 = EUR 0.45378 from the 1999 phase out of the guilder, this is EUR 8.34 million.
[61] The lower estimate corresponds to financing the subsidy using the *flat tax* case, which results here in a lower MEB than the *ad valorem* case. See pages 58 and 60. Given the usage of a conservative lower bound from the literature on the spillover rate, the welfare gain was characterized as "lower limit" as well.
[62] The AIC did not report this figure, which we derived. It would be somewhat lower if the present value of change over the model's 10 year adjustment path had been taken into consideration.
[63] For the 1990/91 fiscal year. The range corresponds to varying the incrementality ratio while holding the other parameters constant, page 239.
[64] Lattimore, page 116, assumes probability distributions (not described) for his mean parameter assumptions to estimate a 75% probability that the 125% incentive is welfare-enhancing (mean social return 31.8%, median 26.5%), with a 67.5% probability for the 150% incentive (mean social return 19.1%, median 15.0%).
[65] Yoon & Lee page 247.

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