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Article

A policy to boost R&D: Does the R&D tax credit work?

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ABSTRACT

In this article we address various issues raised by the evaluation of the R&D tax credit policy. We first consider the studies that estimate the direct effects of the tax credit on R&D inputs. We discuss results obtained through different approaches and methods and show that they give a contrasted picture of the policy's effectiveness. Next we argue that a comprehensive evaluation of the R&D tax credit should include other outcomes and present studies focussing on them. We also initiate a very tentative meta-analysis to obtain a more synthetic view on the various evaluation results. We finally conclude that harmonization and increased comparability in evaluation studies would be useful to bridge the gap between evaluation and policy design and implementation.

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A policy to boost R&D: Does the R&D tax credit work?

1. Introduction

Any government has scarce resources to fulfil their various responsibilities and should therefore make use of them as wisely and efficiently as possible. In the last thirty years there has been an increasing demand from citizens and firms for improved accountability of government management and policies. The need for systematic quantitative evaluations of the efficiency of economic instruments and the use of public resources has now become well-established in the public debate in modern democracies.

In parallel, the emergence of the knowledge-driven economy has led to research and innovation being considered as crucial factors of competitive advantage and main sources of future economic growth. Accordingly, public policies to stimulate investment in Research and Development (R&D) by private firms are actively implemented in most industrialized countries. They are rooted in the concern that due to knowledge spillovers private firms invest less in R&D than would be desirable from society's viewpoint.

The R&D tax credit, which was launched in the early 1980s in the US, France and Canada and which has gained importance and spread to other countries since then, is a major such policy instrument. The large amounts of public money it involves, under the form of forgone tax revenue, make it an obvious object of public-policy evaluations. Asking "Does the R&D tax credit work?" is an important and legitimate question, and indeed a significant international literature has developed to address it.

Concurrently to these evolutions, from a technical perspective, the remarkable progress in data collection, processing and possibilities of diffusion and the development of statistical methods made it possible to conduct much more rigorous and convincing econometric analyses and policy evaluations. In particular, the micro-level data available today allow for more relevant, precise and reliable analyses by providing highly variable and richer information. When also accessible in the form of panels (*i.e.*, not only as a cross-section but also in the time dimension), such micro-data allow for more realistic dynamic model specifications and for useful controls of potential estimation bias resulting from unobserved heterogeneity across firms. International comparisons of econometric studies and policy evaluations, in spite of their many additional difficulties, can also offer important insights and help in improving policy design.

There are two very different kinds of policy evaluations. Implementation evaluations focus on delivery times and deadlines, cost optimization and transparency of public policies; they consist mainly in building indicators and scoreboards, doing specific surveys and applying audit methods. Outcome evaluations which measure the effects of policies on their targets usually take the form of statistical analyses and econometric studies. They are most difficult since outcomes can be uncertain and variable, being affected by many uncontrolled variables and differing in the short and long terms. Policies can also have side effects or unintended consequences, good or bad, besides their targeted outcomes.

This article intends to shed light on the effectiveness of R&D tax credit by explaining how it can greatly differ in its design, by discussing the main methods of evaluations which are used, and by briefly surveying the results of several of the more recent studies, already published or not, in the international literature. Hall and Van Reenen (2000) in their excellent survey article consider a wide array of older articles and review the methods of evaluations from a broadly similar perspective as ours.



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In the next section of the article, we present the R&D tax credit in its different forms within the broader scope of public policies towards research and discuss the various outcomes to be considered for its evaluation. In the third section, we explain the evaluation methods focusing on the direct impacts of the tax credit on firms' R&D expenditures and illustrate them by some of the results of recent analyses. In the fourth section, we consider the much less frequent evaluations that have been conducted for other types of outcomes. In the fifth section we evoke the difficulties of comparing appropriately the results of the various evaluation studies, and illustrate some of these difficulties by presenting a tentative and yet incomplete exercise in meta-analysis. The sixth section concludes.

2. What is the R&D tax credit? Designs, objectives and outcomes

Firms cannot fully appropriate the benefits of their R&D investments: Patents are circumvented in different ways, and valuable process and product innovations are emulated more or less quickly. Even when intellectual property rights are enforced effectively, R&D generates positive externalities that spill over to other firms and benefit the economy at large. Firms thus tend to invest less in R&D projects than they should since they know that other firms will capture part of the returns, or they tend to wait for other firms to engage in R&D projects rather than doing so themselves. As a result firms will normally tend to increase their R&D expenditures to the size where their expected private returns and marginal costs will match, but they will not increase them further to the level that would equalize marginal social costs and marginal social returns and maximize economic efficiency and social welfare. This market failure can be corrected by direct public funding of research activities performed by public research organisations and universities and by economic policies supporting private R&D.

2.1 R&D tax credit and direct subsidies

An R&D tax credit allows firms to deduct part of their R&D expenditure from the corporate tax bill.

The basic idea of the tax credit is to provide a built-in incentive for firms to increase their research activities by allowing them to deduct a share of their corresponding expenditures from their corporate taxes, and thus lowering their cost and increasing their expected returns. It is a relatively recent answer to the need for public intervention in private research and is part of a broader public research policy that, besides the funding and monitoring of public research, mainly includes subsidies directly granted to firms.¹ The R&D tax credit is generally opposed to R&D subsidies, since they have different advantages and downsides. The main advantage of the tax credit is that firms are completely free in choosing, financing and conducting their R&D projects. This argument is consistent with the basic view that profit-maximizing agents make more efficient decisions than centralized authorities. However, it remains possible that firms might use the tax credit to support poor-quality or excessively risky projects.

R&D subsidies consist in funds directly provided to firms applying for financial support of a given research project to specialized public agencies. The main advantage of subsidies is that before being granted, the research projects submitted by the firms are examined and selected by these agencies, which can control their quality and orientation and are ideally able to decide on projects with high social returns. Research subsidies can thus be targeted to specific goals and their implementation can be quite flexible. To a lesser extent, the tax credit can also be modulated with respect to firms' characteristics, in particular their size and overall R&D expenditure. In a number of countries, such as

¹ It also includes the immediate direct deductibility of the major part of R&D investment (wages of R&D personnel and intermediate consumption expenditures of R&D activities) from the base of corporate taxes. This is in contrast to the other types of investments, such as buildings and equipments, which in general have to be amortized over given fiscal service lives.

the Netherlands and Norway, the rate of the tax credit is higher for smaller firms; in France it can decrease for the fraction of eligible R&D expenditure exceeding certain ceilings. Finally, a drawback of subsidies relative to the tax credit is that they involve higher costs both for the firms applying and competing for them and for the public agencies monitoring them.

Hægeland and Møen (2007a) have studied the relationship and relative efficiency of R&D subsidies and the tax credit on the same representative panel of Norwegian firms. They conclude that both instruments are complements at the level of the firm, while they seem to be substitutes at the level of the economy as a whole. They also provide evidence that the tax credit generates more additional private R&D than direct subsidies.

2.2 Main designs

Two main designs of the R&D tax credit can be distinguished, the “volume tax credit” and the “incremental tax credit”. The two have different implications in terms of allocation of the credit and in terms of incentives and efficiency. Deciding which of these two designs is better is still an open question raising many issues, in theory as well as in practice. Before going further, it is useful to shortly recall their main features.

The volume tax credit is based on current R&D expenditures in the fiscal year, either all of them or a part of them depending on their exact definition. For example if the eligible base is the total current R&D expenditures and the rate is equal to 20 percent, then firms can deduct an amount equal to 20 percent of these expenditures from their corporate taxes, implying that at the margin (as well as on average in this simple case) the R&D cost for the firm is 20 percent lower than its market price. Firms that invest in R&D can always benefit from the volume tax credit, irrespective of whether they are increasing or decreasing their R&D expenditures.

The ‘volume tax credit’ applies to total R&D expenditure, the ‘incremental tax credit’ only to spending increases.

By contrast, under the incremental tax credit only firms that tend to increase their R&D expenditures may benefit, since the tax credit is based on the difference between a reference level and the current level of expenditures. This reference level is usually defined as an average of past expenditures. In France at the beginning of the R&D tax credit, from 1983 to 1990, the reference level was simply expenditures in the previous year, and later until 2004 it was the average of expenditures in the two previous years. Thus, the tax credit is positive when R&D expenditures are increasing and negative if they are decreasing. In the latter case, the (negative) tax credit will be deductible from future positive tax credits, if a mechanism of negative tax credit is implemented like it was in France; it will be zero if such mechanism is not implemented. The incremental tax credit is difficult to analyze because its effects are reduced by the fact that current expenditures increase the reference level of the following years. Mixed tax credit policies that are a combination of the two types of tax credit can also be implemented. That was the case of France from 2004 to 2008, when a particularly generous pure volume tax credit was adopted.

Simple microeconomic theory will tend to give preference to the incremental tax credit, since it seems rational for the government to support private R&D only when private marginal productivity is lower than marginal cost while (expected) social marginal productivity is higher. The first-best policy would thus be to subsidize only the R&D activities that firms would not have done in the absence of the tax credit (and only up to the point where their social marginal productivity and cost are equalized). However, the government do not know how much firms would have invested in R&D in the absence of the tax credit, which is difficult to assess. In this setting of asymmetric information, the conservative assumption usually made is that the firm’s R&D expenditures would have been stable (in constant prices) in the absence of the tax credit. The incremental tax credit thus appears as a second-best policy

The incremental tax credit tends to avoid subsidizing R&D that is done anyway but it is more complex and might lead to opportunistic behaviour.

which avoids supporting R&D expenditures that firms would do anyway. In contrast, the volume tax credit subsidizes R&D expenditures in their entirety.

However, the comparison between the volume tax credit and the incremental tax credit involves other considerations, too. In particular, the incremental tax credit can incite firms to adopt opportunistic R&D strategies of stop-and-go and of outsourcing. It is also deemed to be complex and costly for them. The negative tax credit mechanism, when it is implemented, is much criticized for its deterring effect. It cancels out or weakens the tax credit incentives to catch up on R&D activities for firms which have been cutting them down because of economic difficulties and are currently recovering.

Besides the major differences between the volume and incremental tax credit, there exist numerous smaller variations, which may nonetheless matter in practice. Only eligible R&D expenditures can be declared by firms, and eligibility can be defined by law in specific ways, favouring for example cooperative research with academic and public laboratories or the hiring of young PhD researchers, as is currently the case in France. The definition of the tax credit also generally includes one or several ceilings as well as carry-forward and carry-back rules (which allow to transfer to following years the part of tax credit which is higher than the current corporate tax). Such smaller design differences tend to vary across countries and possibly sectors, as well as over time in a given country. They contribute to the complexity of evaluations and to making evaluations more difficult to compare among each other. For example, a volume tax credit with a rate of 30 percent and a ceiling on the total of eligible R&D expenditures is not equivalent to a volume tax credit with a rate of 20 percent and no ceiling, and assessing which one is more efficient is not straightforward.

2.3 Direct objectives and main evaluation outcomes

Although the question of the objective(s) of the R&D tax credit is essential, it is scarcely addressed explicitly. The answer has important implications for the evaluation of the policy. Depending on the objective of the policy, its performance should not be measured in the same way. Thus whether “the R&D tax credit works” depends on the objective(s) and, hence, on what “working” means precisely. Does it mean “increasing R&D investment” – full stop? Or does it mean increasing R&D investment with positive follow-on effects on innovation, productivity, competitiveness, and social welfare?

The objective of the tax credit can also change over time. This point may be illustrated by the French example. When introduced in 1983, the French tax credit was mainly aimed at fostering private R&D (expenditure and R&D personnel). This is still its official objective as part of the Lisbon Strategy of the European Union.² However, it is also considered today as a major fiscal incentive to attract foreign R&D investment and deter French firms from relocating to other countries. The transition from an incremental to a volume tax credit, which multiplies the amount of public funding by a factor of about three, is thus a way to protect the domestic industry and to make it more attractive. It may be viewed as a compensation for lower corporate tax rates elsewhere.

A comprehensive analysis of the objectives of the tax credit should distinguish between those which are directly related to R&D and innovation and those which are less directly related and ultimately target other economic variables. As most of the literature, the scope of this article is limited to the former and to the main outcomes naturally following from them that should be taken into account in

² The Lisbon strategy was defined by the European Council in March 2000 to make the European Union “the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment by 2010”. As far as R&D is concerned, the objective was to reach a ratio of R&D expenditures to GDP of 3 percent by 2010 with the following decomposition: two-thirds for the private sector and one-third for the public sector.

the evaluations of the performance of the R&D tax credit. All in all, the various outcomes that can be considered are the following:

- Impact on existing R&D activities (level or rate of growth of R&D expenditures, R&D-to-output ratios, R&D capital, number of researchers, shares of researchers and engineers in R&D personnel *etc.*);
- Impact on starting R&D activities (as above, *plus* the number of firms performing R&D);
- Impact on innovation output (product and process innovations, patents), productivity (labour and total factor productivity) and other performance indicators (share of “innovative sales”, profitability *etc.*);
- Other (possibly unintended) impacts such as impact on researcher wages; and
- Impact on social welfare (comprehensive cost-benefit analysis).

The results of the evaluation analyses can be presented and summarized in very different ways, which make them often difficult to compare precisely. The results concerning the impact on R&D level and intensity are usually cast in terms of elasticities and multipliers. Elasticities of R&D with respect to the tax credit measure the impacts on R&D expenditures of changes in the tax credit rate. Such elasticities have to be assessed in the short and long run and cannot be directly interpreted in terms of policy efficiency; but they can serve to do simulations of policy changes. Multipliers, also labelled “bang for the buck” (BFTB), estimate the amount of additional R&D (say in euros) that is generated by one euro of tax credit. A number of authors tend to consider that a multiplier above one is an indication that the tax policy is efficient. Conversely, a multiplier below one would point to an inefficient policy on the argument that since one euro of forgone tax receipt generates less than one euro of additional R&D, direct public funding of R&D, through public research or subsidies, would be a better instrument. However, this is not obvious – at least as long as the multiplier is not negative – since in principle what matters is the comparison of the corresponding net social returns.

The ‘bang-for-the-buck’ multiplier is the increase in firms’ R&D per euro of R&D tax credit.

3. Evaluation of the effects of the R&D tax credit on R&D investment

Even when focusing on a precisely defined outcome, evaluations vary widely in terms of methods of analysis. We distinguish four broad methods here: survey analyses; quasi-natural experiments relying on time and policy-design changes; dummy-variable regressions and matching techniques; and structural econometric modelling. We mainly concentrate on the last one, which we tend to prefer. Of course these methods are complementary. They are also related in many respects and the distinction between them is not always clear-cut in practice. As shown below, the dummy-variable regressions and matching techniques can be very close either to quasi-natural experiments or to structural econometric models, depending on how these methods are understood and implemented.

Ideally, one might consider that evaluations should be based on randomized experiments. To adopt the language used in such experiments, we would say that the objective of the tax credit evaluation is to assess whether, and to what extent, a “treatment”, *i.e.*, the tax credit has an effect on the R&D behaviour of firms. Treatment evaluations usually rely on the comparison between the average outcome of a treatment group and that of a control group which is not treated. Of course the allocation of firms to one group or the other must be exogenous and random. Otherwise the treated firms may be intrinsically different from the ones that are not treated. If the allocation is randomized, the control group is considered a valid counterfactual and can be used to determine the outcome the treatment group would have had in the absence of the treatment. The evaluation of new drugs is usually conducted on the basis of such randomized experiments. In the field of economics, experiments have been applied to the evaluation of schooling policies (see Krueger and Whitmore 2001 for a famous example).

A crucial issue when trying to evaluate the R&D tax credit along similar lines is the absence of a directly observable counterfactual, since the implementation of an experiment would imply that only some randomly selected firms receive the tax credit (which is forbidden by competition law). In order to circumvent this limitation, researchers rely on the various methods described in the following subsections. Surveys may be viewed as an undemanding way of constructing a counterfactual by asking beneficiary firms directly “What if you did not benefit from a tax-credit?”, and *vice versa*. In turn, quasi-natural experiments and matching methods use exogenous variations in the design of the tax credit and in the firm’s self-selection to benefit from it, together with appropriate statistical techniques, to overcome the lack of randomization. Finally, structural econometric modelling applies similar statistical techniques but relies more strongly on an economic model of the firm’s behaviour, with the ambition of being more informative in the assessment of policy efficiency.

3.1 Survey analyses

As firms themselves know best what their R&D expenditure would have been absent the tax credit, some studies use surveys.

The survey-based approach relies on the straightforward idea that firms themselves know best what their R&D expenditures would have been in the absence of the tax credit. The multiplier (or BFTB) is simply the ratio between the total expenditures that would have been forgone in the absence of the tax credit and the total amount of the tax credit (possibly adding monitoring costs). Such an estimate, however, does not allow to foretell the effect of future policy changes or to distinguish between short- and long-run impacts. Mansfield and Switzer (1985) in a pioneer survey of the Canadian tax credit find a BFTB equal to 0.3-0.4, which is weak. Hægeland and Møen (2007b) in a recent survey of the Norwegian R&D tax credit obtain a BFTB between 2.12 and 2.65, which is quite high. Yet, contrary to Mansfield and Switzer, they rely on qualitative data to which they assign numerical values in a debatable fashion.

The first limitation of the survey approach is the usually small sample size due to high cost of implementation. The second weakness is limited reliability of the answers. Indeed, surveyed executives may ignore the answers or give incorrect ones because of the intrinsic difficulty to assess the relative weight of all other factors that motivate their R&D decisions. They may also bias the answers for marketing and strategic reasons. On the former, executives in firms where innovation is a marketing argument may not readily admit that the tax credit has a strong incentive effect on their R&D. On the latter, they may exaggerate the effect strategically, anticipating that their opinion would be of some influence in future public-policy decisions.

Although they might not be very reliable to evaluate the overall impact of the tax credit on R&D expenditures, surveys may often appear the best way to bring complementary insights on specific features of the policy (such as special rules aimed at encouraging firms to collaborate with public research laboratories and hiring young researchers). They can also inform policy makers by providing a better understanding and detailed feed-back on industry-specific concerns.

3.2 Quasi-natural experiments relying on time and policy-design discontinuities

These methods rely on discontinuities in the implementation and design of the R&D tax credit policy. A natural idea is to compare R&D expenditures or growth rates of similar firms (preferably the same firms) before and after the introduction of the tax credit. If R&D increases substantially, then it can be argued that such a change can only be explained by the implementation of this policy. Yet, this before-after analysis cannot by itself separate the effect of the tax credit from that of macroeconomic shocks and changes in industry and market trends. Indeed, it could be that the government and firms understand the importance of R&D in a knowledge-based economy at about the same time, inducing the former to launch the tax credit and the latter to increase R&D. In the opposite direction, for example, the current economic crisis might deter firms from increasing their R&D and make governments less

generous. In these cases, the before-after analysis would indicate that the tax credit has a significant effect on R&D even if in fact it does not.

One way to address such an identification problem is the so called difference-in-difference analysis, which takes advantage of a second source of discontinuity. In most R&D tax-credit schemes the total R&D amount eligible for the tax credit is subject to a ceiling above which there is either no tax credit or the rate of the tax credit declines. A ceiling generates such a discontinuity that may be considered as producing a quasi-natural experiment in which firms above the ceiling (*i.e.*, those that are not, or are less, affected by the public policy) can be used as a control group for the firms below the ceiling (treatment group). The difference-in-difference analysis combines the comparison between these two groups with the difference over time, that is, before and after the introduction of the tax credit.

Other studies exploit discontinuities in policy design such as the introduction of a tax credit and a ceiling for the eligible amount.

Hægeland and Møen (2007b) have followed this approach for Norway where a 20-percent volume tax credit was introduced in 2002 with a ceiling of NOK 4 million (about EUR 0.45 million at the time). They argue that the firms which would have had R&D expenditures above the ceiling in the absence of the tax credit do not benefit from tax credit for their marginal units of R&D, whereas the firms which would have had R&D expenditures below the ceiling in the absence of the tax credit do. The latter have stronger incentives than the former to increase their R&D investment and, hence the effect of the tax credit should be higher for them. To determine which two groups of firms would have been respectively above and below the ceiling in the absence of the tax credit, the authors simply select them according to whether their R&D expenditures were already above or below the ceiling in 2001, one year before the introduction of the tax credit. The results show that the firms of the 'below-ceiling group' had indeed a higher rate of growth of R&D from 2001 to 2003 than the 'above-ceiling group'. Their study provides evidence that the Norwegian policy is effective in stimulating R&D, as already suggested by the results of the survey analysis, but it does not allow to quantify the impact of the R&D tax credit accurately.

3.3 Dummy-variable regressions and matching techniques

These methods basically rely on the comparison between the firms that receive the tax credit and the firms that do not. The dummy-variable approach is the simpler one, consisting of econometric regressions of a dependent variable such as R&D expenditures, R&D growth rates or intensity ratios on 0/1- variables indicating whether or not firms have benefited from the R&D tax credit and on a set of other relevant explanatory and control variables.

Hægeland and Møen (2007a and 2007b) follow such a regression approach, too, estimating and testing a number of different specifications on their panel of Norwegian firms. In particular they try to separate short-term from long-term effects and they also try to address the endogenous-selection issue.³ Their estimations yield sizeable and statistically significant stimulating effects. They find that the tax credit increases R&D expenditure by 1.35 percent on average. From their favourite specification they derive a multiplier (BFTB) higher than one (but weakly significant) for the firms above the ceiling and higher than 2 for the firms below the ceiling (highly significant). Duguet (2007) estimates a similar dummy-variable regression on a panel of French firms, taking the rate of growth of private R&D net of the tax credit and subsidies received as the dependent variable. He finds that on average the tax credit increases the rate of growth of private R&D by 0.05 to 0.10 percent but he does not compute the corresponding multiplier.

³ They also include dummies indicating firms' position with respect to the ceiling of the tax credit in addition to the dummy indicating whether or not they benefit from the tax credit. They use sales as an explanatory variable and they take advantage of the panel nature of their sample by controlling for firm fixed effects and year dummies interacted with an indicator of whether the firm R&D was below or above the ceiling before the introduction of the tax credit.

Yet another technique matches beneficiary firms with otherwise comparable non-beneficiary firms.

The matching method is a more general and sophisticated approach than the dummy-variable regression. Basically, it compares the respective outcomes (e.g. the R&D expenditures) of pairs of firms that are alike or as comparable as possible, except for the fact that only one of them has received the treatment (i.e. the R&D tax credit). Since this is the only difference between the pairs of firms, the differences in outcomes can only be explained by the treatment. Of course, in practice it is impossible to find firms that are perfectly comparable, so the comparison is made on the basis of a set of control variables under the assumption that only these control variables have a potential effect on the selected outcomes. In a first step, two groups of firms are created, the treatment and the control group. Each firm in the treatment group is associated with the firm in the control group that is most comparable to it. This association or matching process can be achieved using various techniques. In a second step, the difference in outcomes (for instance, R&D expenditures or R&D intensity) is computed pair by pair, and the average difference between pairs is interpreted as an estimation of the effect of the tax credit.

Duguet (2007) applies the matching method to the evaluation of the effect of the R&D tax credit in France over the period 1993-2003 during which the tax credit was fully incremental and its major features did not change much. The precise purpose of the analysis is to evaluate the effect of the tax credit, considered in a binary way (treatment – no treatment), on the annual rate of growth of private R&D expenditures. When two firms have the same estimated probability to obtain the tax credit but only one asks for it and effectively receives it, then one may assume that the tax credit was randomly attributed. This is an artificial way to create an experiment in which the tax credit is proposed only to randomly-selected firms, using the others as the control group.

In fact Duguet considers two sets of estimates for each year: one computed on the full sample of firms (including firms that do not perform R&D or reduce their R&D expenditure, and hence cannot benefit from the incremental tax credit) and one based on the sub-sample of firms that have increased their R&D expenditures. Working with the sub-sample requires that there are enough firms that qualify for the tax credit but do not ask for it. This may be because (i) firms ignore the existence of the policy; (ii) most of their R&D expenditures are not eligible for the tax credit; (iii) they consider that asking for the credit is too complex and costly; or (iv) they fear that asking for the tax credit increases the likelihood of a tax audit.

The two sets of estimates produce quite different results. Results also vary a lot from year to year and many of them are not statistically significant, with effects on yearly growth rates of R&D ranging from 0.01 percent to 0.1 percent. The estimates obtained from the sub-sample of firms with growing R&D are lower than those obtained on the full sample, which is not surprising. Presenting the results as multipliers (BFTB), Duguet finds a BFTB of zero (one euro of tax credit generates zero additional R&D) for the sub-sample and a BFTB of 2.3 for the full sample. It is difficult to say which control group to prefer.⁴

3.4 Structural econometric modelling

This approach of evaluating the R&D tax credit has been developed by the US Government Accounting Office (1989) and by Hall (1993) and has since been followed by a number of studies for different countries. It follows the traditional framework of 'structural' econometric analysis, relying on an

⁴ The sub-sample might be preferred because the control group (only firms with growing R&D) arguably contains better matches for the treated firms. On the other hand, one might prefer the full sample and consider all non-treated firms as the control group because the tax credit is in principle available to all firms (i.e., firms in the control group can receive it as soon as they start increasing their R&D expenditure again).

economic model of the firm's R&D investment behaviour and using those econometric techniques that seem most appropriate given the model and the available data. The model states that the level of R&D investment of the firm is determined by the user cost of R&D capital, that is, the real cost faced by the firm when it makes an R&D investment decision, which is a function of the rate of the tax credit scheme, among other variables. "Other things being equal", the higher the R&D user cost, the lower the R&D investment. One advantage of the approach is that it allows a more informative evaluation of the policy and of policy changes.

The structural econometric approach thus does not directly estimate the effects of the R&D tax credit on R&D but involves two main steps, namely:

- Computing the response of the user cost of R&D to changes in the rate of the tax credit also taking into account other characteristics of tax credit design (incremental *versus* volume tax credit, existence of ceilings etc.); and
- Specifying and estimating an econometric model of the response of the firm's R&D investment or -capital to changes in the user cost of R&D capital.

The user cost of R&D capital, like any rental cost is defined as the cost of using one unit of capital for one year (Hall and Jorgenson 1971). The user cost involves the price to buy this one unit of capital, the interest rate that could have been generated by the money used to buy it, the unit's economic rate of depreciation and an inflation gain or loss⁵. It also depends on the corporate tax rate of the firm, the specific fiscal rules of amortization of R&D and the characteristics of the R&D tax credit.

Usually the econometric model is a regression of R&D capital or investment on the user cost of R&D capital and a set of explanatory firm-specific variables (in particular sales), involving different lags of these variables to take into account the firm dynamic behaviour. It thus allows estimating short-run and long-run own-price elasticities of R&D capital (*i.e.* the time profile of variations of R&D when the user cost changes). When panel data are available, individual firm effects may be included to correct for unobserved heterogeneity (*i.e.* unobserved, albeit relevant, variables that vary across firms but not over time are practically constant over time). Under an incremental or mixed tax credit scheme, the user cost of R&D is endogenous since it depends on the level of R&D expenditures.

To evaluate the R&D tax credit in France, Mairesse and Mulkey (2004) rely on such an econometric model for an unbalanced panel of 2,431 firms (mainly in the manufacturing sector) over the 18-year period 1980-1997. They find a long run elasticity of R&D capital to its user cost of -2.7 , providing evidence of a positive and significant effect of the tax credit on R&D expenditures. The authors also make a policy simulation for 2003. They assume an increase of the statutory rate of the incremental tax credit by 20 percent (from 50 percent to 60 percent) together with an increase of the tax-credit ceiling by 20 percent too. Such a policy change would have generated between EUR 168 million and EUR 320 million of additional private R&D expenditures, substantially more than the additional government expenditures on the tax credit (EUR 88 million or 20 percent). The BFTB multiplier is thus between 2 and 3.6. That is, one euro of tax credit generates between EUR 1 and EUR 2.6 of additional private R&D.⁶

5 That is, if the price of one unit increases during the year, the user cost is reduced because at the end of the year the firm can sell the unit of capital at a price higher than the buying price.

6 In an update Mairesse and Mulkey (2008) use the analysis on a similar sample but over the 24 years 1980-2003 and find an even stronger effect on R&D capital of a decrease in its user cost. Their provisional estimation of the long-term elasticity of R&D capital with respect to its user cost appears to be about twice as high as that before. However the BFTB multiplier corresponding to a similar simulation as the one in their 2004 study remains of about the same order of magnitude.

Several articles have recently been published on the evaluation of the R&D tax credit in Spain. They are all based on panel data samples covering the 1990s, constructed from the same firm survey (*Encuesta Sobre Estrategias Empresariales*). The Spanish tax credit has changed several times since its introduction and has a mixed design, combining a volume base and an incremental base (Romero and Sanz 2007). All these analyses distinguish small firms from large firms, showing that the results are different for the two groups and suggesting that the tax credit can be more cost efficient when taking into account the size of the firms.

Marra (2004) finds a user-cost elasticity of R&D expenditures of -0.6 and -0.8 for small and large firms, respectively, and an elasticity of the user cost to the tax credit rate of about -0.5 for both types of firms, and hence a combined elasticity of R&D to the tax credit rate of about 0.3 for small firms and 0.4 for large firms. Corchuelo (2006) obtains a higher user-cost elasticity of R&D expenditures (-1.2). Romero and Sanz (2007) find a user-cost elasticity of R&D expenditures of about -1.0 and an elasticity of the user cost to the rate of tax credit of about -1.5 , and hence a combined elasticity of R&D to the tax credit rate of 1.5 .⁷ They also compute a BFTB multiplier equal to 0.25 , suggesting that the R&D tax policy is not very efficient.

The R&D tax credit seems to be more efficient in France and in Norway than in Spain and in the Netherlands.

One of the most recent studies following the user-cost structural econometric method is the evaluation of the Dutch R&D tax credit (WBSO) by Lokshin and Mohnen (2009). The WBSO is a volume tax credit which is based on R&D labour costs and has two ceilings defining a first bracket with a higher tax credit and a second one with a lower tax credit.⁸ As in Mairesse and Mulkey (2004) but for a smaller and shorter unbalanced panel (of 400 firms for the period 1996 to 2004), the authors compute a firm-specific user cost of R&D capital which depends on the characteristics of the R&D tax credit and they estimate the user-cost elasticity of R&D capital considering various dynamic regression specifications and taking care of the endogeneity of the user cost in different ways. They find significant short-run user cost elasticities ranging from -0.2 to -0.5 depending on the dynamic specification and long-run elasticities ranging from -0.5 to -0.8 . To compute a BFTB multiplier, Lokshin and Mohnen also simulate a counterfactual scenario in which the tax credit does not exist and estimate how much firms would have invested in R&D in such a scenario. They obtain that on average for all firms the multiplier is about 0.5 , but that it is significantly higher at 1.2 for small and medium-sized firms (SMEs) with less than 250 employees and smaller at 0.4 for large firms.

4. Evaluation of the effects of R&D tax credit on other outcomes

This section aims at providing a more comprehensive view of the tax-credit evaluation by completing the input-oriented approach presented and developed in the previous section. It evaluates the effect of the tax credit on other outcomes, namely the decision to start R&D, R&D output, researcher wages and social welfare.

4.1 Effects on the decision to start R&D

Increasing R&D can be achieved through stimulating the firms that already perform R&D but also through encouraging firms (in particular SMEs) to start R&D. The evaluation of the tax credit's impact on the decision to start R&D raises specific and difficult issues. Engaging in R&D activities even at a

⁷ Romero and Sanz use a somewhat different approach based on a system of demand equations (not only an R&D equation), derived from a cost function as in Fuss (1977), but on a much smaller sample than Marra and Corchuelo.

⁸ In 2004 firms could deduct 42 percent below a first ceiling of EUR 110,000 of their R&D labour cost and 14 percent above this ceiling and up to the second ceiling set at EUR 7.9 million.

small scale involves various fixed and learning costs for the firm, on which there is little or no information. The decision to start investing in R&D may justify special policy provisions.⁹

The lack of appropriate information is a major reason why only very few evaluation studies have considered the issue in spite of its importance. More research on the process of engaging in R&D would help to shed light on the following questions:

- What are the determinants of the decision of firms to perform R&D? For example, exports are highly positively correlated with R&D but it is hard to disentangle which is the cause and which the effect.
- Do fiscal incentives really encourage firms to start R&D activities? One could fear that fiscal incentives might not be sufficient to trigger the decision to invest in R&D. One could also think that fiscal incentives incite firms to reveal R&D activities they already have or to redefine informal innovation activities as R&D. The true impact of the tax credit would thus be difficult to distinguish from a revelation or re-labelling effect.
- Is the true tax credit impact on real beginners a long-lasting one or is the pool of potential R&D-performing firms rapidly exhausted?
- Is it really efficient to push small firms to start R&D activities? If fixed costs and economies of scale are important, it should not be surprising that the majority of small firms cannot afford to invest in R&D and be strong innovators.
- From a technical-evaluation point of view, making progress in explaining the decision to start R&D would also help in controlling for the potential selection bias in assessing the impact of the tax credit on R&D-performing firms.

Corchuelo (2006) in her evaluation of the Spanish tax credit estimates a generalized Tobit model with the user cost of R&D capital in both the selection probit equation and intensity regression. She obtains a significant user-cost elasticity of the probability to do R&D of about -2.7 . Hægeland and Møen (2007b) in their analysis of the Norwegian R&D tax credit find that in 2003 and 2004, just after the introduction of the tax credit, the firms that did not perform R&D two years earlier had a higher probability by about 7 percent to engage in R&D than in 1995-2001, but that this is not true anymore in 2005, suggesting that the pool of firms likely to engage in R&D was largely exhausted by then.

The R&D tax credit also raises the probability that firms start doing R&D.

4.2 Innovation outputs and productivity

Under the assumption that the marginal productivity of R&D is decreasing within firms, additional R&D generated by the tax credit would be less productive and could lead to only limited achievements. It is thus important to be able to evaluate the R&D tax credit not only in terms of R&D inputs but also outputs. Two variables are usually considered to measure R&D outputs: the number of patents granted to or applied for by the firm and the process and product innovation indicators reported in innovation surveys. These are of course imperfect measures because not all patented or reported innovations are productive for the firm or the economy as a whole. A realistic vision of the innovation-production process would also require taking time into account. A patent or a reported innovation may be the result of several years of research on a project, and the average duration of a project depends on the industry and the type of research (fundamental, applied or development).

⁹ Stimulating firms to engage in R&D for the first time has been a constant objective of the French tax credit policy since its beginning in 1983. Also the current system of a pure volume tax credit applies a specific tax credit rate for firms starting R&D activities. For these firms the rate is equal to 50 percent in the first year and 40 percent in the second, with the ordinary rate of 30 percent applied as from the third year.

The effect of the R&D tax credit on patents and product and process innovations should also be translated into firm productivity and sales. The firm model developed by Crépon, Duguet and Mairesse (1998) – known as the CDM model – offers an econometric framework to analyze these issues. It relates R&D, innovation and productivity in a three-step model. The first step accounts for the firm decision to do R&D and for its R&D intensity. The second step explains innovation (either in terms of patents, process and product innovation indicators, or the share of new or improved products in sales) as a function of R&D and other variables. The third step is a regression of productivity on innovation and the traditional factors of production (labour and physical capital intensity).

It would be possible to combine the CDM model with the structural modelling approach described in Sub-section 3.4 by including a user cost of R&D capital in the first-step intensity equation and in the selection equation. The direct effect of the R&D tax credit on firm R&D expenditure and its indirect effects on innovation and productivity could thus be estimated consistently in the CDM framework. As far as we know, this has not been attempted, probably because of data limitations and intrinsic econometric difficulties.

Czarnitzki *et al.* (2005) focus on the effect of the tax credit on innovation, using matching techniques for a large representative cross-sectional sample of Canadian manufacturing firms. They take advantage of the information which is provided by the 1999 Survey of Innovation conducted by Statistics Canada. They rely particularly on four product innovation variables. The first two are binary indicators of whether the firm introduced an innovation that was new to Canada or new to the world, while the third is the number of new or significantly improved products produced by the firm and the fourth is the share of these innovative products in sales.

Czarnitzki and his coauthors are thus able to compare the innovation outputs of the firms that receive the R&D tax credit with those of firms that do not. As Duguet (2007), they consider two control groups: the first based on all firms that do not benefit from the tax credit, the second based only on the firms that perform R&D but do not apply for the tax credit.¹⁰ They show that Canadian firms that receive the tax credit declare a higher number of product innovations, are more likely to generate innovations new to the market and have a higher share of total sales accounted for by innovative products. They thus conclude that the Canadian tax credit encourages firms to do more R&D, which leads to innovations valued by the market.¹¹

Canadian firms benefiting from the R&D tax credit are found to introduce more new products and to have a higher share of sales from innovative products.

4.3 Researchers' wages

Public policies in general may have unintended or side effects, positive and negative, which should be taken into account by policy makers when designing or modifying policies. The possibility of an increase of R&D prices and particularly of researchers' wages is the side-effect of the R&D tax credit that is most often acknowledged, though it is still little studied. An R&D tax credit that strongly stimulates firm R&D expenditure may foster the demand for R&D personnel, resulting in an increase in their wages, at least in the short run, if the supply of such personnel is relatively inelastic. In this situation, the additional R&D expenditures fuel higher R&D prices and do not correspond to effective additional R&D. Still, this does not directly imply that the policy is a failure as the price increase is likely to trigger

¹⁰ Here again, the construction of the second control group implies that a number of firms could apply for the tax credit but do not do so. In matching tax credit recipients with non-recipients, the authors also use various other control variables: the size of the firm, its R&D organization (whether R&D is performed internally or contracted out), its R&D intensity, its price-cost margin, its operations in new markets, and industry dummies as well as geographical dummies accounting for differences in the tax credit scheme across provinces.

¹¹ However, in complementary analyses, the authors find no evidence that the tax credit encourages firms to start R&D or contribute to increasing productivity, profitability or their market shares.

an increase in supply and to lead to an increase in the economy's R&D capital and personnel in the long run. Thus the tax credit may have effects on the price of R&D (i.e. the interest rate on R&D capital and researcher wages) and on the stock of R&D and the number of R&D personnel. Assessing the efficiency of the tax credit includes focusing on those matters, but only a few researchers have done so.

Goolsbee (1998) has initiated such a research with a study on the income of 17,700 researchers and engineers, using information from the US Current Population Survey (for the period 1968-1994) and macroeconomic data. He runs regressions of individual incomes on the shares of R&D spending to GDP and government-funded R&D to GDP, which also includes a set of covariates aimed at capturing the effect of economic trends and individual characteristics. He finds that there is a positive and significant relation between R&D spending and the income of R&D personnel, and argues that this is a causal relation showing that R&D spending has a strong and significant effect on the R&D personnel's wages. The conventional estimates of the effect of R&D policies would be largely overestimated because of this effect. Goolsbee's analysis, however, is not fully convincing since it does not take into account, for example, gains in the productivity of researchers and it does not explicitly address the question of reverse causality (the government supports private R&D because it is more and more costly).¹²

Rising researcher wages weaken the volume effect of the R&D tax credit today but help ensure higher supply of researchers in the long run.

Notwithstanding its weaknesses, Goolsbee's analysis raises a question that should be part of a comprehensive evaluation of R&D policies. Answering the question of R&D-price effects requires a precise identification strategy. Indeed, it is likely that a common underlying movement may account for both the implementation of R&D policies and the increase in R&D personnel productivity. For instance, globalization puts pressure on the innovative capacities of firms and countries in industrialized countries, which may increase wages to attract more productive personnel and urge governments to strengthen R&D policy. Two recent studies on firm data concur in finding that the effect of the R&D tax credit on the wages of R&D personnel is rather weak. Haegeland and Møen (2007b) estimate that the wage effect could amount to a reduction of 0.3 of the high BFTB multipliers they obtain for Norway (one third of a dollar of tax credit goes into higher wages). Lokshin and Mohnen (2008), in a companion paper to their main analysis for the Netherlands, find an estimate in the order of 0.10 for the elasticity of R&D wages with respect to the fraction of the wage bills supported by the Dutch tax credit scheme.

4.4 Social welfare

Social welfare is more complex an outcome to measure than R&D expenditure. The evaluation of a policy in terms of social welfare should be done in the framework of a cost-benefit analysis taking ideally into account all the significant direct and indirect effects of the policy on the economy and society. The R&D tax credit is considered efficient in terms of social welfare if it stimulates innovation and productivity over and above boosting R&D and if it does so without mobilizing resources that could be used more efficiently elsewhere. To our knowledge, the only attempt of an evaluation of the R&D tax credit policy on social welfare is Parsons and Phillips (2007). In their cost-benefit analysis for Canada, the effects of the tax credit on social welfare work through five main channels which are quantified in cent per dollar and which sum up to the global net effect of the policy:

- The tax credit stimulates R&D investment to reach a socially more efficient level, helping to bridge the gap between the level that is optimal to individual firms and the optimal level for society. Its primary effect is thus the social return in the form of R&D externalities ('spillovers');
- The tax credit increases the producer surplus of firms by lowering the cost of each unit of R&D as well as stimulating them to do more R&D at this lower cost;

¹² Reverse causality also partly invalidates Goolsbee's other central result, namely that government-funded R&D crowds out private R&D activity (as evidenced in a negative correlation between the ratios of government-funded R&D and private R&D to GDP).

Evaluations should consider the tax credit's impact on social welfare in a cost-benefit analysis accounting for R&D spillovers and administrative and opportunity costs.

- The tax credit has a direct social cost equal to the amount of tax revenue forgone;
- The tax credit also has compliance and administration costs affecting both firms and the authorities; and
- The tax credit has an opportunity cost since the forgone tax revenue could have been used to fund other public expenditures or other tax cuts.¹³

Parsons and Phillips carefully survey many previous studies to calibrate the benefits and costs for all five channels. All in all, the median increase in social welfare would be around 10 cents per dollar of tax credit, suggesting that the Canadian tax credit policy is indeed socially efficient. However, the authors also analyze the sensitivity of this result to the uncertainty and imprecision of the different estimations underlying their calibration, and they show that even within a range of small variations, the global net effect of the policy on social welfare can be either positive or negative. This illustrates the limitations of such a cost-benefit analysis, which is as difficult as it is ambitious.

5. Comparability of evaluations and a tentative exercise in meta-analysis

As evidenced by the recent studies presented above, evaluations of the tax credit may yield contrasting results, even when focussing on a definite outcome such as the BFTB multiplier. An isolated evaluation study can give very useful indications on the effectiveness of a given policy in a specific context. But comparisons of studies in different countries and for different periods may provide insights on what policy design characteristics may be more appropriate and efficient than others. Such comparisons would thus be more helpful to policy makers faced with the decision whether or not to introduce an R&D tax credit or how to radically reform an existing tax credit policy. However, taking stock of the results of the various studies raises great difficulties, and the best way would be to compare them in the framework of a meta-analysis, trying to take into account the main sources of differences. This section first stresses these sources of differences and then presents an incomplete and tentative attempt of meta-analysis mainly to illustrate.

5.1 Limits to the comparability of evaluation studies

The comparison between different evaluation analyses should in principle help policy makers in assessing the efficiency and improving the design and implementation of public policies. Yet, the various evaluations of the R&D tax credit yield very different and potentially contradictory results. How to interpret such differences in evaluation results? To what extent is it possible and indeed legitimate to compare these evaluation results? The comparison in terms of BFTB multipliers seems attractive for at least three reasons. First, they are easy to understand for non-specialists and give a synthetic idea of the policy's efficiency. Second, they seem to provide a standardized way of presenting the results and making them directly comparable across countries, periods, and tax credit characteristics. Third, all the estimates stemming from the various evaluation methods can, in principle, be converted into corresponding multipliers. All in all, and although limited to the one outcome of additional R&D expenditures, BFTB multipliers seem to be a good yardstick for the comparison of tax credit evaluations. Parsons and Philips (2007) also strongly argue for using them as a first basis of comparison.

¹³ The alternative use considered by Parsons and Phillips is the allocation of lump-sum tax refunds to citizens and firms that are equivalent to the expected tax expenditure for the R&D tax credit. However, allocating the funds to public research and higher education would have been politically more realistic alternatives.

Ideally, differences in estimated multipliers should mainly reflect differences in policy efficiency. However, they are more or less precisely estimated and can be biased to a varying degree. Studies conducted for the same country and same time period may find very different results, as evidenced, for example, by the contrast between Mairesse and Mulkay (2004; 2008) who find that the French tax credit is efficient by following an econometric structural approach, and Duguet (2007) who reach a similar conclusion or a far less optimistic one (depending on the control group chosen) by applying matching techniques.

The differences in the BFTB multiplier between studies in practice may reflect:

- Genuine differences in policy efficiency. These differences are the ones of interest for policy makers.
- Methodological differences. Some methods may be more demanding than others; they may also be more relevant and generate more informative results.
- Country heterogeneity. For various reasons such as industry composition, market structure, features of economic policy in general and corporate tax policy in particular, firms in different countries might react differently to identical tax credit policies.
- Time differences. Studies conducted over different periods may yield diverse results because of changes in the national economic situation and international environment. Depending on the length of the study period, long-term effects may be more or less reliably identified and more or less precisely estimated.
- Publication biases (Ashenfelter *et al.* 1999). Such biases can arise from the fact that authors may have a natural tendency to look for positive results and that it is easier to publish articles showing a significant impact of a policy than those showing no effect.

Estimated multipliers do not only reflect differences in policy efficiency but also differences in evaluation methods and country heterogeneity.

Estimated BFTB multipliers from different evaluation studies should thus be compared with great caution and not be taken for granted “naively”. Gathering them and examining them in the framework of a ‘meta-analysis’ is probably the best way to control for potential sources of differences unrelated to true efficiency and make the results more comparable. Yet, the relatively limited number of evaluations of the R&D tax credit coupled a relatively large variety of methodological approaches, policy designs and economic contexts, makes it a challenge to attempt such a meta-analysis.¹⁴ Also, many studies also do not present results in the form of a BFTB; some of them do not document standard deviations or confidence intervals; some also provide so many different estimates, depending on various assumptions, that it is hard to make a choice of the one(s) to be selected in a meta-analysis. In spite of all these difficulties, there is value in gathering most of the studies that assess the impact of the R&D tax credit in terms of BFTB multipliers (and/or elasticities) and in carefully comparing them, even if not in the framework of a formal meta-analysis.

In the future, policy makers should also support efforts to enhance comparability and harmonization in evaluation practices of R&D tax incentives (European Commission 2006 and 2008). Without preventing researchers from using different methods of investigation and trying to improve them, a harmonized framework of evaluation and a set of recommendations should be defined and agreed upon at the level of the European Union or the OECD countries. This would contribute to widening the scope of evidence-based policy decisions. Instead of simply answering the question “Is this policy design efficient?” it would help answer the question “Which is the most efficient design?”.

¹⁴ A “simple” meta-analysis would consist in running a regression of the BFTB multipliers estimated in a “sufficiently” large sample of studies on a set of dummies indicating at least the country, type of tax credit and main evaluation method.

5.2 An incomplete and tentative meta-analysis

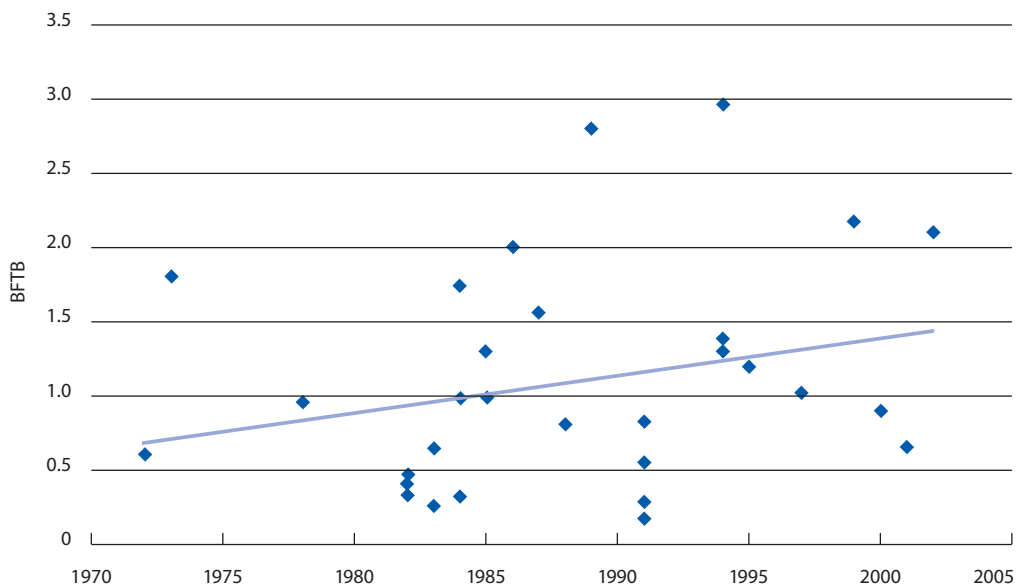
A careful meta-analysis of the R&D tax-credit evaluations including a number of potentially relevant control variables in a regression setting would imply a tremendous effort. Still, it is possible to give a feeling of what kind of insights one could gather from a first step towards such a meta-analysis.

Parsons and Phillips (2007) have already adopted a meta-analytical approach, focused on the country dimension, when they compare the country averages of the estimated R&D tax credit impacts in studies available for Canada and the United States. They find that on average the BFTB multiplier is equal to 0.91 in Canada compared with 1.42 in the United States. This suggests that the American R&D tax credit is more efficient than the Canadian one, with one dollar of tax credit generating 50 cents more of R&D in one country than in the other. From the policy maker's standpoint, this could be interpreted in terms of relative efficiency of policy designs. Since the American tax credit is incremental whereas the Canadian one is a volume tax credit, one could be tempted to conclude that the incremental design is preferable to the volume design. The gap in tax credit efficiency could also be imputed to country heterogeneity but this is not too convincing in the present case since the United States and Canada are commercially integrated and their economies are comparable in terms of general organization and performance.

Relying on 33 BFTB multiplier estimates, mostly gathered from the studies quoted by Parsons and Phillips (2007), we first look whether results differ in the time dimension. An increasing trend might indicate some overall progress in tax policy design and implementation and in learning by firms. Yet a significant trend (positive or negative) could also reflect improvement in evaluation methods. In order to assign a year to each estimate, we take the average year of the study period. For example, we assign the multiplier estimated by Mairesse and Mulkey (2004) to 1989, the mid-point of their sample period (1982-1996). The BFTB estimates and their average years of estimation are reported in the Annex (Table A1). Figure 1 plots the estimated BFTB multipliers on the Y-axis and the corresponding sample mid-point years on the X-axis.

The effectiveness of the R&D tax credit appears to have increased over the past 30 years.

Figure 1. Estimated BFTB multipliers over time



Source: See Annex Table A1

The linear regression adjusted through the data points shows that the BFTB estimates tend to increase over time at a (weakly significant) average annual rate of 2.5 percent¹⁵. This is rather huge, implying an overall average increase of 60 percent in the 30 years from the earliest to the latest estimates. Of course such a result should be taken with a pinch of salt, but at least it does not contradict the idea that the R&D tax credit policies might have been increasingly efficient over the years, possibly because of the sharing of good practices in launching or reforming policy designs and in their implementation.

We also look for some evidence of publication bias, relying on the method developed and used by Ashenfelter *et al.* (1999) who analyze the numerous estimates of returns to education. A basic reason for the existence of a publication bias is that at equal levels of scientific quality, a study showing that an effect is positive as expected and significantly different from zero is more likely to be submitted for publication and published than another study showing that this effect is insignificant or even negative. As a result, the average of the estimates from published studies would tend to be an overestimation of the true average effect.

Since it is much more difficult, if not impossible, to access unpublished publications, finding evidence of a publication bias is of course a challenge. Ashenfelter *et al.* make the point that in the absence of a bias there is no reason why the precision of published estimates (as measured by the standard error) should depend on their magnitude and, hence that we should not observe a significant correlation between these estimates and their standard errors. By contrast, if there is a publication bias, one might expect to find a positive correlation between the published estimates and their standard errors. Indeed, when the level of precision decreases (increasing standard errors), higher estimates are more likely to be reported than lower ones. A significantly positive correlation between reported estimates and standard errors thus gives some presumption of a publication bias, even if it could also be due to other factors¹⁶.

If higher 'bang-for-the-buck' estimates are less precisely estimated, this might point to a publication bias.

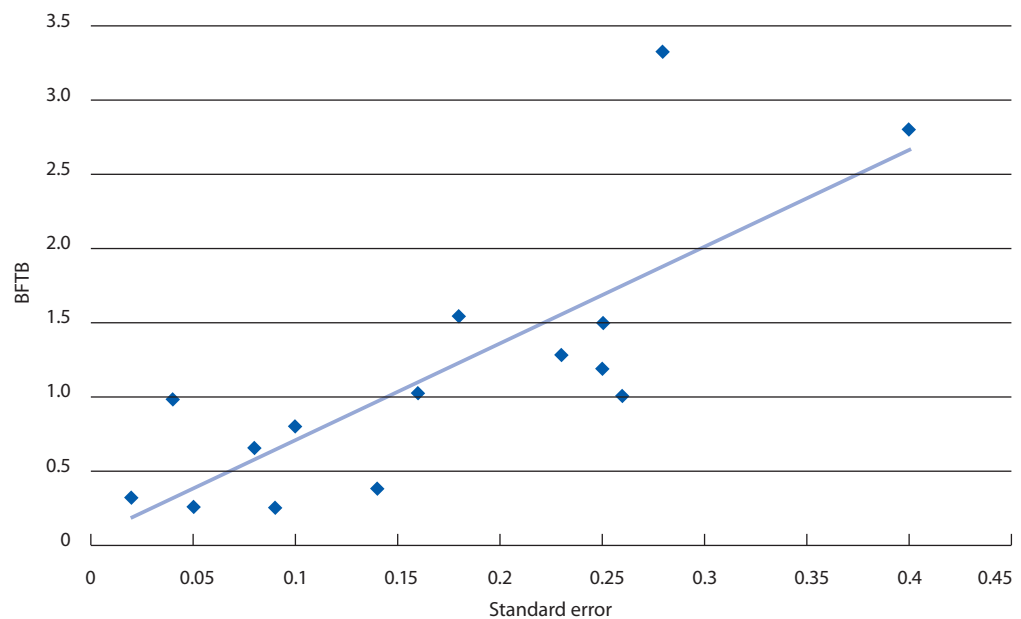
In Annex Table A2 we report those 15 estimated BFTB multipliers (out of the 33 presented above) for which we are able to retrieve standard errors. In fact many studies do not provide standard errors for the BFTB multipliers, so we compute them whenever it seems possible. When a 95-percent confidence interval is provided, we derive the standard error of the estimate using the fact that it is approximately normally distributed and thus that the length of the 95-percent confidence interval is four times the standard error. Otherwise, when a study was reporting various estimates under different hypotheses and methods, we assume boldly that the 95-percent confidence interval is equal to the range between the maximum and minimum reported estimates.

The following Figure 2, which plots the BFTB multipliers on the Y-axis and their corresponding standard errors on the X-axis, shows a strong positive and highly significant correlation between the two (correlation coefficient of 0.79). The correlation remains very high and significant (at about 0.73) when we delete the two highest estimates with also the highest standard errors. This suggests that there might be a publication bias leading to overestimating the efficiency of the R&D tax credit. Although our evidence at this point must be taken with caution, it clearly calls for a thorough meta-analysis that should be based on a larger sample of estimates with standard errors and include a variety of controls.

15 The standard error is of 1.7, corresponding to a Student *t*-value of 1.5 with 31 degrees of freedom and a unilateral *p*-value of 7.5 percent.

16 For example, instrumental-variable estimates of R&D user cost elasticities, which correct for measurement errors in the user cost tend to be higher and to have higher standard errors than estimates which do not correct for such errors.

Figure 2. BFTB multipliers estimates and standard errors



Source: See Annex Table A2

6. Conclusions

We have seen that a comprehensive evaluation of the R&D tax credit involves a number of different questions. In particular, the efficiency of the policy should be assessed through its effect on several outcomes. So far the literature has concentrated on the effect on R&D inputs, in general R&D expenditure, which is a natural first step for all evaluation. The results obtained through various methods and for various countries are very different, which makes it hard to answer the question “Does the R&D tax credit work?” in a clear-cut way.

The effect of the tax credit on R&D inputs varies widely across countries and studies.

The results reported here give indeed a contrasted picture. Hægeland and Møen (2007b) gather strong evidence that the Norwegian tax credit is efficient. It is noteworthy that their estimates appear to be particularly robust because they are constant across various methods. For France, Mairesse and Mulkey (2004; 2008) conclude that the French tax credit efficiently stimulates R&D expenditures on the basis of a structural econometric model. However, studies following the same approach for other countries like the one for the Netherlands by Lokshin and Mohnen (2009) and those for Spain come to less optimistic conclusions.

Overall the evidence obtained in terms of BFTB multipliers appears to be more scattered than the evidence from estimated elasticities with respect to the user cost of R&D capital. While these elasticities cannot be directly translated into measures of efficiency, they are useful to simulate small policy changes. However, they are probably not reliable in predicting the effects of radical policy changes. For example, it is likely that the marginal effect on R&D expenditures, and hence the BFTB multiplier, will decrease when the rate of the tax credit or its ceiling is strongly increased or when an incremental tax credit is replaced by a volume tax credit.

While the body of research on the tax credit's impact on firm R&D investment is rich, evidence is much scarcer for other outcomes of interest for economic policy, such as the probability to engage in R&D, innovation and productivity as well as social welfare. The few articles considering these outcomes are examples that should be followed in future policy evaluations. The BFTB multiplier is not a fully satisfactory measure of efficiency because it concentrates on how much additional R&D expenditures were generated per euro of tax credit but does not inform on higher-order goals of the tax credit policy.

The fact that the BFTB is below or above the benchmark of one tells us whether the additional private R&D is entirely funded by the government or whether it is also funded by the firm and in what proportion. It does not tell to what extent firms' additional R&D contributes to increasing their own innovations and productivity and to fostering positive research externalities to the benefit of other firms and the economy at large. The more fundamental question is about the overall social return on the additional private R&D net of social costs. As the careful attempt of a full cost-benefit analysis for Canada by Parsons and Phillips (2007) shows, this is also the most difficult question to answer.

In any case, the need for harmonization and for increased comparability is obvious throughout this article, and maybe is its major conclusion. This objective could be reached through a consensus on the outcome variables to be studied, on the choice and implementation of evaluation methods and on the ways to present results. The development of a meta-analysis framework adapted to the R&D tax credit – and to fiscal incentives more generally – is a relevant and important direction for future research.

There is a need for harmonizing evaluation methods, and more research should be devoted to effects on innovation and social welfare.

Annex

Table A1. Studies and estimates used in Figure 1 in the main text

Ref.	Authors	Year of publication	BFTB	Studied year	Country
1	McFetridge and Warda	1983	0.60	1972	Canada
2	Mansfield and Switzer	1985	0.39	1982	Canada
3	Mansfield	1985	0.34	1982	Sweden
4	Bernstein	1986	1.28	1985	Canada
5	Mansfield	1986	0.45	1982	US
6	Gen. Accounting Office	1989	0.26	1983	US
7	Cordes	1989	0.64	1983	US
8	Baily and Lawrence	1992	1.30	1985	US
9	Tillinger	1991	0.25	1983	US
10	Hall	1993	2.00	1986	US
11	Hines	1993	1.55	1987	US
12	Bureau of Ind. Eco.	1993	0.80	1988	Australia
13	Berger	1993	1.74	1984	US
14	McCutchen	1993	0.32	1984	US
15	Shah	1994	1.80	1973	Canada
16	Mamuneas and Nadiri	1996	0.95	1978	US
17	Lebeau	1996	0.98	1985	Canada
18	Abt Associates	1996	1.38	1994	Canada
19	Dagenais <i>et al.</i>	1997	0.98	1984	Canada
20	Bloom <i>et al.</i>	1997	0.54	1991	Australia
21	Bloom <i>et al.</i>	1997	0.28	1991	Canada
22	Bloom <i>et al.</i>	1997	0.18	1991	France
23	Bloom <i>et al.</i>	1997	0.82	1991	US
24	Van den Hove <i>et al.</i>	1998	1.20	1995	Netherlands
25	Brouwer <i>et al.</i>	2002	1.02	1997	Netherlands
26	Poot <i>et al.</i>	2003	1.02	1997	Netherlands
27	Klassen <i>et al.</i>	2004	1.30	1994	Canada
28	Klassen <i>et al.</i>	2004	2.96	1994	US
29	Mairesse and Mulkay	2004	2.80	1989	France
30	Cornet and Vroomen	2005	0.65	2001	Netherlands
31	Duguet	2007	2.17	1999	France
32	Hægeland and Møen	2007	2.10	2002	Norway
33	Lokshin and Mohnen	2009	0.90	2000	Netherlands

Table A2. Studies and estimates used in Figure 2 in the main text

Ref.	Authors	Year	Country	BFTB	Std Error
2	Mansfield and Switzer	1985	Canada	0.39	0.14
4	Bernstein	1986	Canada	1.28	0.23
6	Gen. Accounting Office	1989	US	0.26	0.05
9	Tillinger	1991	US	0.25	0.09
11	Hines	1993	US	1.55	0.18
12	Bureau of Industry Eco.	1993	Australia	0.80	0.10
14	McCutchen	1993	US	0.32	0.02
17	Lebeau	1996	Canada	0.98	0.04
24	Van den Hove <i>et al.</i>	1998	Netherlands	1.20	0.25
34	Bureau Bartels	1998	Netherlands	1.50	0.25
26	Poot <i>et al.</i>	2003	Netherlands	1.02	0.16
29	Mairesse and Mulkey	2004	France	2.80	0.40
30	Cornet and Vroomen	2005	Netherlands	0.65	0.08
31	Duguet	2007	France	3.33	0.28
31	Duguet	2007	France	1.01	0.26

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