ISSN 1725-7565 (PDF)
ISSN 1725-7557 (Printed)

European Commission

TAXATION PAPERS

WORKING PAPER N. 52 – 2014

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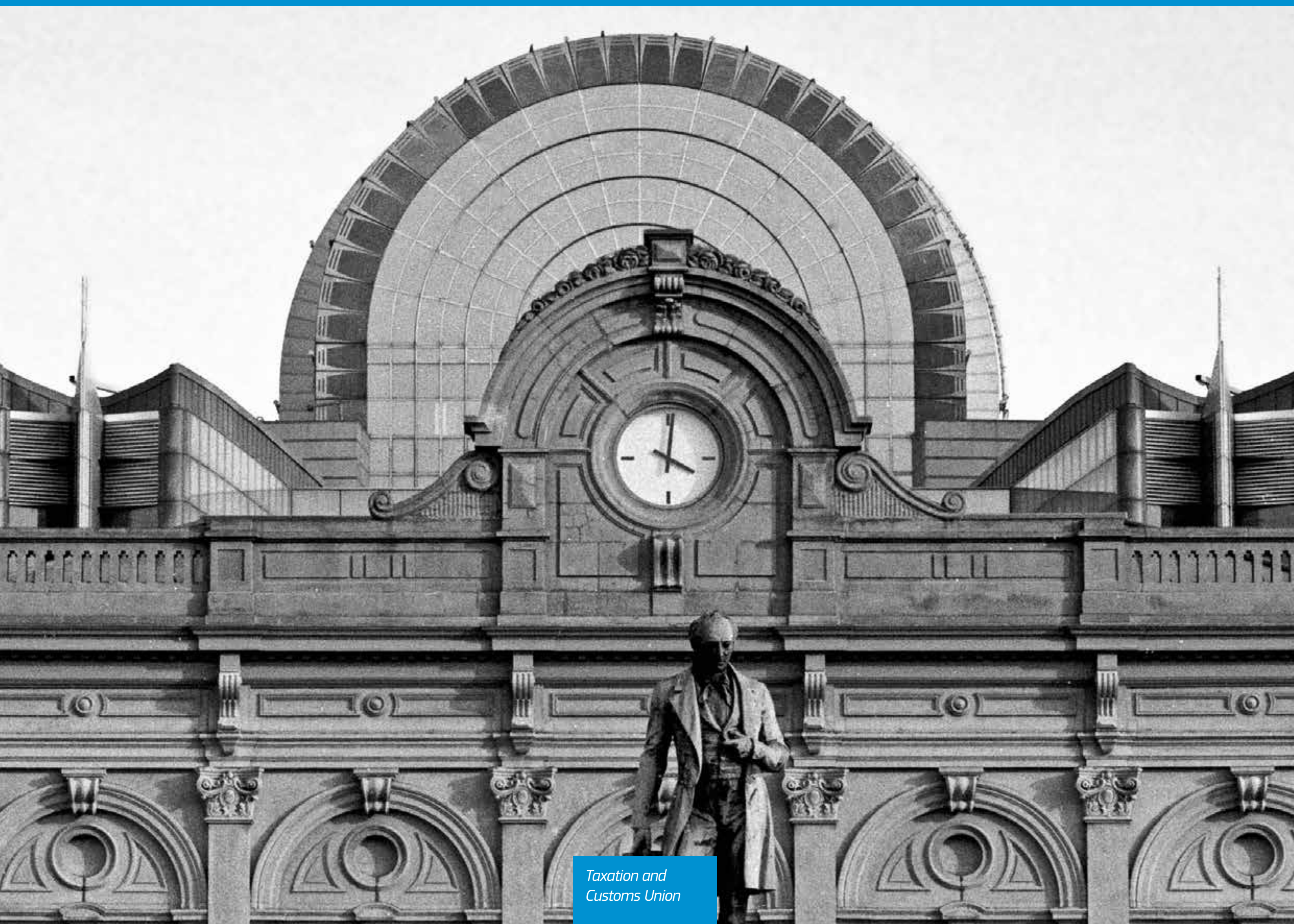
A Study on R&D Tax Incentives

Final report



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Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2014

doi:10.2778/29775 (printed)
ISBN 978-92-79-44563-7 (printed)

doi:10.2778/447538 (PDF)
ISBN 978-92-79-44562-0 (PDF)

A Study on R&D Tax Incentives

FINAL REPORT

TAXUD/2013/DE/315
FWC No. TAXUD/2010/CC/104

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In consortium with:
CAPP
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The Hague, 28 November 2014

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A Study on R&D Tax Incentives

Summary

Interest in the effectiveness of tax incentives for Research and Development (R&D) has spurred in the aftermath of the financial crisis - and for two different reasons. First, the financial crisis obliged many governments to introduce tough fiscal consolidation measures. This has increased the urgency to balance expenditure on innovation policy against expenditure on other policies. Another reason is that the drop in economic activity put even more emphasis on the need to find new sources of growth.

R&D tax incentive schemes are widely adopted in advanced economies, including innovation leaders like the United States and Japan. Within the EU, only Germany and Estonia currently do not have a tax policy aimed directly at stimulating innovation. Although tax incentives are common, they are far from homogeneous and differ substantially across the 33 countries surveyed in this report,[1] with most countries offering more than one type of instrument. R&D tax credits are the most popular type of incentive (present in 21 countries), followed by enhanced allowances (sixteen countries) and accelerated depreciation (thirteen countries).

The vast majority of tax incentives are based on corporate income taxes, while eight countries have (additional) incentives that apply to social contributions and/or wage taxes. Tax benefits applying to income from innovation (mostly *patent boxes*) are proliferating. At the moment of writing, eleven EU member states offered corporate tax reduction for income resulting from to intellectual property.

In the past fifteen years countries have shifted from tax incentives that only apply to increments in a firm's R&D expenditure (incremental schemes) towards incentives that apply to total R&D expenditure (volume-based schemes). Currently, only seven countries have incremental tax incentives, usually in combination with a volume-based scheme, and for two of them - Ireland and United States - this design element is phasing out.

While tax incentives are essentially a generic policy instrument, targeting to specific groups of firms is quite common. Ten countries explicitly target small- and medium-sized enterprises. Six countries target young companies. In ten countries, tax incentives are also differentiated according to the legal status of firms. For example, some schemes have smaller tax benefits for foreign-owned companies as is the case in Canada. Most countries put a ceiling on the amount that firms can receive and in five countries the generosity of the scheme decreases with the size of a firm's R&D expenditure.

Do R&D tax incentives work?

The widespread use of R&D tax incentives in times of economic slowdown raises the question of how effective these policy instruments are. The vast majority of studies surveyed in this report conclude that R&D tax credits are effective in stimulating investment in R&D. The estimates of the size of this effect are widely diverging and are not always comparable across countries due to differences in methodology. Studies that are more rigorous find that one euro of foregone tax revenue on R&D tax credits raises expenditure on R&D by less than one euro.

Whether R&D tax incentives work ultimately depends on how many innovative products, services, and production processes they induce. Unfortunately, the impact of

[1]Besides the member states of the European Union also Canada, Israel, Japan, Norway, and the United States were analysed.

R&D tax incentives on innovation and productivity is less studied. The limited evidence seems to point towards a positive impact of R&D tax incentives on innovation.

The effects of R&D tax incentives on R&D expenditure vary across sub-groups of firms, with most studies focusing on firm size. In some of the countries analysed, small and medium sized enterprises (SMEs) tend to respond more strongly to the support for R&D, while the reverse was found in other countries. These seemingly contradictory results make it difficult to draw general conclusions. There is some evidence that the impact for start-up firms can exceed the average impact.

Recent evidence suggests that knowledge spillovers of large firms exceed those of small firms. This finding weakens the case for targeting tax incentives towards SMEs - even when SMEs would increase their R&D expenditure more strongly in response to incentives.

The impact of R&D tax credits may be highly sensitive to their design and organization, but empirical studies on the effects of design and organizational features are scarce. One aspect that is relatively well-studied is whether incremental schemes perform better than volume-based schemes. Both kinds of designs have been found to result in additional R&D expenditure, but the evidence on which type of scheme is more effective is mixed.

Do patent boxes work?

A large body of literature has identified that multinational firms engage in profit-shifting activities in order to decrease their overall tax liabilities. Intangible assets, like patents, play an important role as their location of origin can be quite arbitrary. Tax incentives for income generated by R&D, mostly patent boxes, can result in large decreases in tax revenue for all governments, including those engaging in such a policy.

Tax incentives for R&D expenditure reward firms for the societal benefits from innovation that they themselves are unable to appropriate. It is hard to make the argument that a patent box serves the same purpose: patent boxes introduce a preferential rate for income from innovations that are already protected by Intellectual Property Rights (IPR's). IPR's enable firms to capture a large part of the societal benefits, such that the need for a tax incentive for protected innovations becomes unclear. The impact on innovation of patent boxes is difficult to evaluate empirically as tax planning and tax competition induce measurement error in innovation indicators.

What is good practice?

In the absence of comparable evidence on the performance of specific R&D tax incentives, more than 80 tax incentives in 31 countries have been benchmarked. The benchmarking is based on twenty *principles of best practice*, which are divided over three categories: 1) scope of the instrument: how does the tax incentive work, which expenditures are eligible, 2) targeting: does the instrument target specific types of firms, explicitly or implicitly, and 3) organizational practice: how does the application procedure work and is the tax incentive evaluated?

One of the best practice principles proposed in this report is that volume-based R&D tax credits are preferred over incremental ones. Incremental R&D tax incentives may trigger firms to change the timing of their R&D investment plans. For example, incremental schemes make it more attractive for firms to gradually increase their R&D investment than to do a single large investment now if profits from these investments will materialize later in time. Also, incremental schemes result in higher administrative and compliance costs. As incremental schemes probably are not more effective than volume-based schemes, the higher costs of incremental schemes make volume-based schemes a better practice. The vast majority of instruments are volume-based.

Another good practice principle proposed in this report is that tax incentives should only be aimed at R&D activities that are likely to contribute to the world-wide stock of knowledge, rather than support activities limited to advancement in firm's own state of expertise. The impact of a tax incentive on innovation will depend strongly on the strictness of its novelty requirement. Without any novelty requirement, a tax incentive could stimulate imitation, rather than innovation. Especially for countries close to the technology frontier, such a scheme could reduce innovation instead of promote it. Countries that are lagging in terms of innovation might catch up faster if they allow for imitation of foreign innovations. A number of R&D tax incentive schemes have strict novelty requirements, including in Canada and the United Kingdom.

Tax incentives should ideally apply to those types of expenditures that bring about strong knowledge spillovers. Tax incentives based on the wage bill paid to researchers can be considered best practice in this context, for example because they are likely to generate higher knowledge spillovers than other types of R&D expenditure: researchers move from one employer to another and take their former's employers knowledge with them. A practical advantage of tax incentives for R&D wages is that they have lower administration and compliance costs. Tax credits for researcher wages can be found in The Netherlands and Belgium, amongst others (see Table 5.2 for an overview).

Young companies, rather than SMEs in general, are probably more likely to bring the innovations that challenge large incumbent firms. A favourable environment for entrepreneurs might not only contribute to a country's innovativeness but also to the flexibility of its economy. Targeting young companies can be considered a better practice than targeting SMEs. A scheme which has been identified as a good practice and explicitly targets young firms is the French tax credit for young innovative enterprises (Jeunes Entreprises Innovantes).

As R&D expenditure may precede revenue generated by innovation by several years, it is good practice to provide a carry-over facility and an option to receive the benefit even in case a company is not profitable (cash refunds). Such features offer firms more flexibility and certainty for investment decisions. This is especially relevant for young companies that typically are not profitable in the first years of operations. While most of the R&D tax incentives analysed offer a carry forward facility, cash refunds are available only in nine countries.

With respect to the organization of a tax incentive it is good practice to have a one-stop, online application procedure. This is already in place in majority of the countries. In addition, the time it takes for tax authorities to make a decision on eligible expenses should be as short as possible, not exceeding a year. Several countries have already introduced an option to receive an immediate refund for smaller companies, as these firms are typically more liquidity constrained.

Systematic evaluations are also recommended. High-quality firm-level data is indispensable for a rigorous quantitative evaluation and should be collected according to international standards. For seventeen countries no evaluation study has been found. Currently, only few countries have frequent evaluations, for example The Netherlands and France. The quality of evaluation studies is mixed and in many cases does not meet the standards of peer-reviewed academic journals.

A ranking of R&D tax incentives

The scores of tax incentives on the twenty best practice principles are used to compute an overall index. The instrument that has the highest overall benchmarking score is the French tax credit for young innovative enterprises (Jeunes Entreprises Innovantes). It provides generous support to young SMEs for which R&D expenditure represents at least fifteen percent of total costs. The novelty requirement of R&D is according to best practice ("new to the world"). The immediate refund option and short response time means that firms can obtain the funding faster.

The Norwegian SkatteFUNN tax credit comes second. This largely generic scheme only offers a preferential rate to SMEs. The application procedure of the R&D tax credit is quite simple: firms can apply online, one-stop agency is available and several guides are available. The introduction of the policy involved a public consultation and it has been evaluated various times. The third position is taken by the Accelerated amortization in Denmark, which has a good organizational practice and does not target specific groups of firms.

Overall, the eighty R&D tax incentives show substantial heterogeneity in their designs and organizational practice. In part this reflects differences in country characteristics (like innovation systems and tax rates), but there are also substantial opportunities for improving R&D tax incentives across the European Union - in particular with respect to the organization and scope of the tax incentives.

Résumé

L'intérêt quant à l'efficacité des incitants fiscaux en Recherche et Développement (R&D) a été stimulé à la suite de la crise financière - pour deux raisons différentes. En premier lieu, la crise financière a contraint de nombreux gouvernements à mettre en place des mesures de consolidations fiscales rigoureuses. Cela a accru l'urgence d'équilibrer les dépenses en matière d'innovation par rapport aux dépenses liées à d'autres domaines d'actions publiques. La seconde raison est que la baisse de l'activité économique souligne encore plus le besoin de trouver de nouvelles sources de croissance.

Les schémas d'incitants fiscaux en R&D sont largement adoptés dans les économies avancées, y compris par les leaders de l'innovation comme les États-Unis et le Japon. Au sein de l'UE, seules l'Allemagne et l'Estonie n'ont actuellement aucune politique fiscale visant directement la stimulation de l'innovation. Bien que les incitants fiscaux soient communs, ils sont loin d'être homogènes et diffèrent beaucoup á travers les 33 pays observés dans ce rapport,[2] la plupart des pays offrant plus d'un type d'instrument. Les crédits d'impôts en R&D sont le type d'incitant le plus populaire (présent dans 21 pays), suivi par les régimes de déduction plus favorables (seize pays) et la dépréciation accéléré (treize pays).

La majorité des incitants fiscaux se fondent sur les impôts sur les revenus professionnels, tandis que huit pays proposent des incitants (supplémentaires) qui s'appliquent aux cotisations sociales et/ou à l'impôt sur le salaire. Les avantages fiscaux s'appliquant aux revenus d'innovation (le plus souvent les *patent boxes*) sont en plein essor. Au moment de l'écriture de ce rapport, onze membres de l'UE proposaient une réduction de la taxe professionnelle pour les revenus attribuables à la propriété intellectuelle.

Au cours des quinze dernières années, les pays sont passés d'incitants fiscaux qui s'appliquent uniquement aux augmentations des dépenses en R&D de l'entreprise (incitants incrémentaux) à des incitants qui s'appliquent aux dépenses en R&D totales (incitants basés sur le volume). Actuellement, seuls sept pays ont des incitants fiscaux incrémentaux, et dans deux d'entre eux - l'Irlande et les États-Unis - cet élément disparaît progressivement. Les incitants fiscaux en R&D sont également devenus plus généreux pendant la crise économique, plusieurs pays ayant accru le taux des bénéfices et élargi la définition des dépenses éligibles.

Tandis que les incitants fiscaux sont essentiellement un instrument stratégique générique, cibler des groupes spécifiques d'entreprises est assez commun. Dix pays visent explicitement les petites et moyennes entreprises. Six pays visent les jeunes entreprises. Dans dix pays, les incitants fiscaux sont également différentiés en fonction du statut légal des entreprises. Par exemple, certains incitants ont des bénéfices fiscaux moins importants pour les entreprises sous contrôle étranger. La plupart des pays fixe une limite au montant que les entreprisse peuvent recevoir et dans cinq pays, la générosité de l'incitant diminue au fur et à mesure que les dépenses en R&D d'une entreprise augmentent.

Est-ce que les incitants fiscaux en R&D fonctionnent ?

L'utilisation largement répandue des incitants fiscaux en R&D, à une époque de ralentissement économique, soulève la question de savoir à quel point ces instruments politiques sont efficaces. La grande majorité des études analysées dans le cadre de ce rapport arrive à la conclusion que les crédits d'impôts en R&D sont efficaces pour

[2] En plus des États membres de l'Union Européenne, le Canada, Israël, le Japon, la Norvège et les États-Unis ont été également analysés.

stimuler les investissements en R&D. Les estimations de l'importance de leur impact sont très variées, et ne sont pas toujours comparables entre les pays en raison des différences de méthode. Des études plus approfondies révèlent qu'une perte de recette fiscale d'un euro sur les crédits d'impôts en R&D, entraine une dépense en R&D de moins d'un euro.

L'efficacité des incitants fiscaux en R&D dépend surtout du nombre de produits, services et processus de production innovants qu'ils entraînent. Malheureusement, l'impact des incitants fiscaux en R&D sur l'innovation et la productivité a été moins étudié. Les preuves limitées semblent indiquer un impact positif des incitants fiscaux en R&D sur l'innovation.

Les effets des incitants fiscaux en R&D sur les dépenses en R&D varient selon les classes d'entreprise. La plupart des études se concentrent sur la taille des entreprises. Dans certains des pays analysés, les petites et moyennes entreprises (PME) réagissent plus fortement à l'aide dans le domaine de R&D, alors que l'inverse a été trouvé dans d'autres pays. Ces résultats, apparemment contradictoires, rendent une conclusion générale difficile. Certains résultats montrent que l'impact pour les start-ups peut dépasser l'impact moyen.

Des résultats récents suggèrent que les diffusions de connaissances de grandes entreprises dépassent celles de petites entreprises. Cette résultat constatation limite entraîne que les incitants fiscaux sont moins accordés aux PME - même si les PME augmentaient plus fortement leurs dépenses en R&D comme réaction aux incitants.

L'impact des crédits d'impôts en R&D peut être très sensible à leur conception et à leur organisation, mais les études empiriques sur les effets des caractéristiques de concept et d'organisation sont rares. Un aspect relativement bien étudié est celui de savoir si les incitants incrémentaux sont plus efficaces que les incitants basés sur le volume. Il s'avère que les deux sortes d'incitants entraînent des dépenses en R&D supplémentaires, mais les preuves permettant de savoir quel type d'incitant est le plus efficace sont mitigées.

Est-ce que les patent boxes fonctionnent ?

De nombreux documents ont identifié que des entreprises multinationales s'engagent dans des activités de transfert de bénéfices afin de diminuer leur dette fiscale générale. Les actifs immatériels, comme les brevets, jouent un rôle important car l'endroit où ils ont été créés peut être arbitraire. Les incitants fiscaux pour les revenus générés en R&D, le plus souvent les patent boxes, peuvent résulter en des réductions importantes des revenus d'impôts pour tous les gouvernements appliquant une telle politique.

Les incitants fiscaux pour les dépenses en R&D forment un dédommagement pour les entreprises des avantages sociaux de l'innovation qu'ils sont eux-mêmes incapables d'attribuer. Il est difficile de présenter l'argument qu'une patent box sert à la même chose : les patent boxes mettent en place un taux préférentiel pour le revenu des innovations déjà protégées par les droits de propriété intellectuelle. Ces droits permettent aux entreprises de profiter d'une large partie des bénéfices sociaux, de sorte que le besoin d'un incitant fiscal pour les innovations protégées n'est pas très clair. L'impact sur l'innovation des patent boxes est difficile à évaluer de manière empirique, car la planification et la concurrence fiscales impliquent des erreurs de mesure dans les indicateurs d'innovation.

Qu'est-ce que la bonne pratique ?

En l'absence de données de comparaison sur l'efficacité des incitants fiscaux spécifiques au R&D, plus de 80 incitants fiscaux ont été comparés dans 31 pays. La comparaison se fonde sur vingt *principes de bonnes pratiques,* qui sont divisés en trois catégories : 1) étendue de l'instrument : comment est-ce que l'incitant fiscal fonctionne, quelles dépenses sont concernées, 2) cible : est-ce que l'instrument cible certains types spécifiques d'entreprise, explicitement ou implicitement, et 3) pratique organisationnelle : comment est-ce que la procédure de requête fonctionne et l'incitant fiscal est-il évalué ?

L'un des principes de meilleures pratiques proposés dans ce rapport est que les crédits d'impôt en R&D basés sur le volume sont préférés aux incitants incrémentaux. Les incitants fiscaux en R&D incrémentaux peuvent pousser les entreprises à modifier le calendrier de leurs projets d'investissement en R&D. Par exemple, les incitants incrémentaux incitent les entreprises à augmenter progressivement leur investissement en R&D, plutôt que de faire un seul investissement important immédiatement, si les bénéfices de ces investissements se matérialiseront plus tard. De plus, les incitants incrémentaux impliquent des frais administratifs et de conformité plus élevés. Les frais plus élevés des incitants progressifs ne sont apparemment pas compensés par une efficacité plus importante comme les simulations récentes le montrent - même pour une croissance faible de l'entreprise. La majorité des instruments se fondent sur le volume.

Une autre bonne pratique proposée dans ce rapport est que les incitants fiscaux doivent uniquement viser les activités R&D pouvant potentiellement contribuer aux connaissances mondiales, plutôt que de promouvoir les activités limitées à accroître l'expertise propre de l'entreprise. L'impact d'un incitant fiscal sur l'innovation dépend fortement de la rigueur de cette exigence de nouveauté. Sans aucune exigence de nouveauté, un incitant fiscal peut stimuler l'imitation plutôt que l'innovation. Notamment pour les pays proches de la frontière technologie, un tel incitant pourrait réduire l'innovation au-lieu de la promouvoir. Les pays en retard en termes d'innovation peuvent rattraper leur retard plus vite s'ils permettent l'imitation d'innovations étrangères. Quelques schémas d'incitants fiscaux en R&D comportent des exigences d'innovation strictes, comme au Canada et au Royaume-Uni.

Les incitants fiscaux devraient s'appliquer idéalement aux types de dépenses qui entraînent de fortes diffusions de connaissances. Les incitants fiscaux basés sur le salaire payé aux chercheurs peuvent être considérés comme un exemple de bonne pratique dans ce contexte. Par exemple, parce qu'ils mènent probablement à une meilleure diffusion de connaissances que les autres types de dépenses en R&D : les chercheurs passent d'un employeur à l'autre et emportent avec eux les connaissances de leurs anciens employeurs. L'un des avantages pratiques des incitants fiscaux pour les salaires en R&D est qu'ils impliquent des frais administratifs et de conformité moins importants. Des crédits d'impôts pour les salaires des chercheurs sont proposés notamment aux Pays-Bas et en Belgique (voir tableau 5.2 pour un aperçu).

Les jeunes entreprises, plutôt que les PME en général, ont plus de chances de fournir des innovations qui concurrenceront les grandes entreprises. Un environnement favorable aux entrepreneurs contribuera non seulement aux innovations du pays, mais également à la flexibilité de son économie. Cibler de jeunes entreprises peut être considéré comme une meilleure pratique que cibler des PME. Un incitant qui a été identifié comme une bonne pratique et qui vise explicitement les jeunes entreprises, est le crédit fiscal français pour les Jeunes Entreprises Innovantes.

Comme les dépenses en R&D viennent plusieurs années avant les revenus générés par l'innovation, ce serait une bonne pratique de fournir une facilité de crédit-pont, et une possibilité de recevoir une allocation, même si l'entreprise n'est pas encore rentable (remboursements en espèces). De telles fonctions offrent aux entreprises une plus grande flexibilité et une meilleure assurance pour les décisions d'investissement. Cela est notamment important pour les jeunes entreprises qui ne sont en général pas rentables aux cours des premières années d'exercice. Alors que la plupart des incitants fiscaux de R&D analysés proposent un crédit-pont, les remboursements en espèces sont uniquement proposés dans neuf pays.

En ce qui concerne l'organisation d'un incitant fiscal, une procédure unique de requête en ligne est une bonne pratique. Elle est déjà appliquée dans la majorité des pays. De plus, la durée de prise de décision des autorités fiscales sur les dépenses concernées doit être aussi courte que possible et ne pas dépasser une année. Plusieurs pays ont déjà mis en place l'option de recevoir un remboursement immédiat pour les petites entreprises car la liquidité de celles-ci est souvent limitée.

Des évaluations systématiques sont également recommandées. Des données de haute qualité sont indispensables au niveau des entreprises pour une évaluation quantitative rigoureuse. Elles doivent être collectées en respect de normes internationales. Dans dix-sept pays, aucune étude d'évaluation n'a été trouvée. Actuellement, seuls quelques pays font l'objet d'évaluations fréquentes, par exemple, les Pays-Bas et la France. La qualité des études d'évaluation est mitigée et dans de nombreux cas, elle ne satisfait pas les normes des publications universitaires spécialisées.

Classement des incitants fiscaux en R&D

Les scores des incitants fiscaux sur les vingt principes de meilleures pratiques ont été utilisés pour mettre au point un indice général. L'instrument qui a obtenu le score le plus élevé lors du benchmarking est le crédit d'impôt français pour les Jeunes Entreprises Innovantes. il fournit un soutien généreux à de jeunes PME, pour lesquelles les dépenses en R&D représentent au moins quinze pourcents des coûts totaux. La nécessité d'innovation en R&D est conforme à la meilleure pratique (« nouveau dans le monde »). L'option de remboursement immédiat et de temps de réponse court signifie que les entreprises peuvent recevoir plus rapidement un remboursement.

Le crédit d'impôt norvégien SkatteFUNN arrive en seconde position. Cet incitant, d'ordre surtout générique, offre un taux d'imposition préférentiel aux PME. La procédure de requête de crédit d'impôt en R&D est assez simple : les entreprises peuvent s'inscrire en ligne, une agence est disponible ainsi que plusieurs manuels. L'introduction de la politique a impliqué une consultation publique, et elle a été évaluée à plusieurs reprises. La troisième position est occupée par les amortissements accélérés au Danemark, qui a obtenu des scores élevés pour la pratique organisationnelle, et qui ne cible pas un groupe spécifique d'organisations.

Au total, les quatre-vingt incitants fiscaux en R&D présentent une grande hétérogénéité dans leurs formats et leurs pratiques organisationnelles. Cela reflète en partie les différences entre les caractéristiques des pays (comme les systèmes d'innovation et les taux d'imposition) mais il y a également des opportunités conséquentes d'amélioration des incitants fiscaux en R&D dans l'Union Européenne – en particulier en ce qui concerne l'organisation et l'étendue de ces incitants.

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1 Introduction

Europe 2020, the strategy for growth set out by the European Commission, puts investment in research and development (R&D) as one of the five priorities for Europe to become more competitive.[3] By the year 2020, European investment in R&D should reach at least three percent of gross domestic production (GDP). The target of three percent is ambitious given that expenditure on R&D was about 2.1 percent in 2012. However, progress has been made, as in the period before 2007 expenditure was 0.3 percentage point smaller than it currently is.

The financial crisis has impacted the course for reaching the target in various ways. First, the financial crisis obliged many governments to introduce tough fiscal consolidation measures, prioritizing other issues over R&D. In 2012 the share of public R&D expenditure in total government spending was lower than in 2007 for half of the EU member states[4]. The urgency to balance expenditure on innovation against expenditure on other policies, calls for clarity on the performance of the different innovation policy instruments.

Second, the drop in economic activity put even more emphasis on the need to find new sources of growth. Innovation is such a source - and one which is underutilized in Europe: recent evidence suggests that European firms have significantly lower rates of return in R&D than American firms (Cincera and Veugelers, 2014).

The conviction that innovation policy can reduce budget deficits by stimulating economic growth is part of the "smart consolidation" approach. This approach considers innovation policy to be part of the solution rather than part of the problem. For smart consolidation to work, innovation policy needs to be very effective in increasing innovation - otherwise other policies (including reducing taxes) might be preferable. In addition, innovation policy needs to be effective in the context of a severe recession, which raises the bar as firms are challenged by a lack of demand for their (new) products. The gap of innovative performance between the member states is closing. However, there are still significant differences. Traditionally, the most innovative countries - Sweden, Denmark, Germany and Finland - are performing around three times better than the least innovative states (European Commission, 2014). These countries also have the highest gross domestic expenditure on R&D relative to GDP (see Figure 1.1 below).

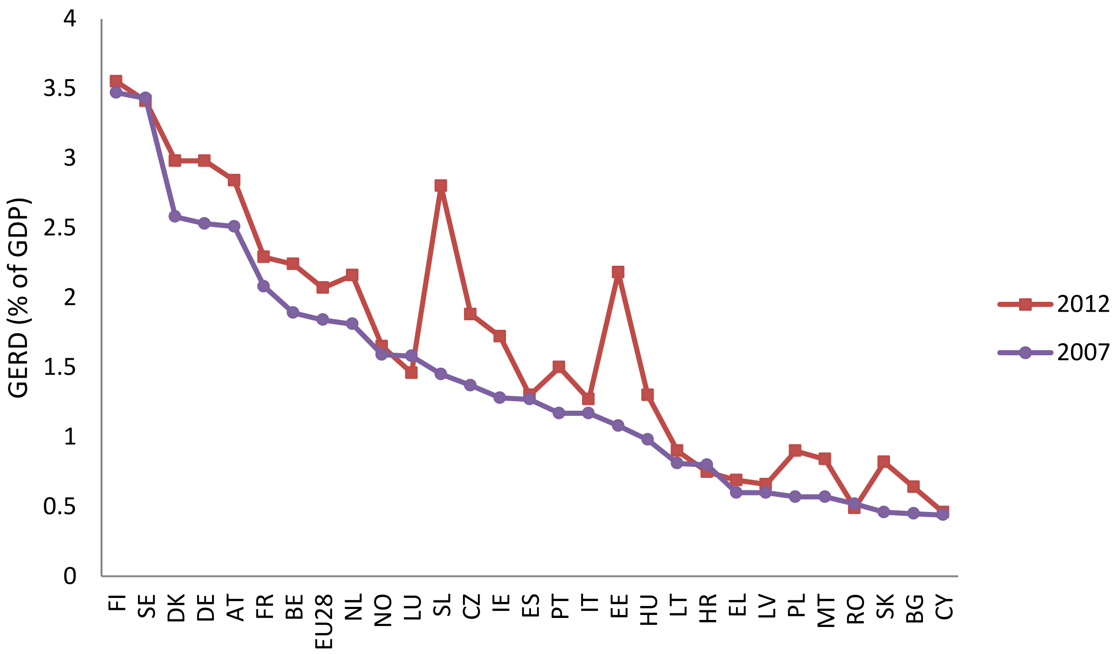
The scope for policies to support more innovation in the high-performing countries might be limited, but there could be substantial opportunities for the other Member States to catch-up, as shown by the example of Slovenia and Estonia.

Catching-up of countries with low R&D expenditures is also crucial for Europe as a whole to reach the goals set out in the Europe 2020 strategy. This requires that especially under-performing countries need to revise their policies regarding innovation. Learning from the experiences of other countries can be valuable for upgrading innovation policy.

[3] The other targets relate to employment, climate change and energy sustainability, education, and poverty and social exclusion

[4] Eurostat data on "Share of government budget appropriations or outlays on research and development as % of total general government expenditure", *available at*: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsc00007&plugin=0

Figure 1.1 Gross domestic expenditure on R&D (% of GDP)



Source: Eurostat, Gross domestic expenditure on R&D, 2014

The foregone tax revenue of R&D fiscal incentives is substantial. Thus, understanding the effectiveness of this policy instrument is ever more important in times when governments look for ways to balance budgets and find new sources of growth. This study aims to facilitate this task and motive better policy by:

1. providing insight in the effectiveness of R&D tax incentives
2. giving an overview of existing R&D tax incentives, and
3. identifying good practices and benchmarking policies.

1.1 R&D tax incentives and the innovation policy mix

Why should governments have policies that stimulate innovation? It is widely agreed that technological change is an important contributor to long-term growth (Aghion and Howitt, 1992; Romer, 1990). New ideas translate in new and better products and improved productivity, which eventually increases general welfare. But markets left on their own will probably generate less innovation than would be desirable from society's point of view. The reason is that knowledge is not completely excludable: ideas can be easily copied and used by other firms. Non-excludability discourages firms to invest in research since the returns to investment will not entirely accrue to the firm. The social rate of return on R&D is thus higher than the private rate of return. This externality leads to suboptimal outcomes for society (Arrow, 1962).

A second reason why markets might fail to deliver sufficient innovation is that investments in research are more risky. This makes it more difficult for investors and banks to monitor innovative firms: information asymmetry between the innovator and the investor is large. As a result, firms will find it difficult to obtain funding. Especially young innovative enterprises suffer from this problem as they lack collateral and track record.[5]

R&D tax incentives are one of the most popular innovation policy tools. Essentially, they reduce taxes for firms that have R&D expenditure (input-related R&D tax incentives) or for firms that have income from commercializing intellectual property rights (output-related R&D tax incentives). Input-related R&D tax incentives decrease the price of R&D inputs faced by firms, which makes it more attractive to engage in R&D. Output-related R&D tax incentives increase the returns from innovative products that are protected by IPR. This should motivate firms to invest in innovation or to attract foreign R&D firms.

In the recent years, R&D tax incentives have gained attention. Currently, 26 EU and 27 OECD member states provide fiscal incentives for R&D.[6] The advantage of R&D tax incentives lies in their generic nature: decisions on R&D investments are left to the market and are not steered by the government. In general, profit-maximizing agents are more likely to make more efficient allocations than central authorities (a general reference is Hart et al. (1997)).

A drawback of R&D tax incentives is that firms will first invest in projects with highest private, rather than social returns (Hall and Van Reenen, 2000). Public research and subsidies for private research do not have this bias towards private returns as the government can directly influence the type of supported projects.

Public research and subsidies for private research could also be more effective than R&D tax incentives when the commercialization of products is extremely difficult to keep exclusive to the firm, like education or health. These types of projects do not provide attractive investment opportunities, no matter how low the offered tax rate would be. Innovation of this kind can be considered a public good[7] and will only be provided if it is financed directly by the government.[8]

Direct government funding for private research has several disadvantages vis-à-vis R&D tax incentives. First, it results in substantially larger administrative costs. Furthermore, government do not have an information advantage as to which projects will succeed or potentially bring highest social returns. Besides, the quality of decisions on subsidies can be eroded by short-term political goals and impacted by lobbying (Hall and Van Reenen, 2000).

More pragmatically, R&D tax incentives can be effective tools to reach the targets set under the Europe 2020 strategy as foregone tax revenue accounts is considered government expenditure on R&D policy. They can also be used to attract international footloose R&D (OECD and World Bank, 2014).[9]

Yet, innovation does not happen in a closed system but in an open environment. Thus, whether instruments targeted at raising the level of R&D, like R&D tax incentives, will result in more innovation depends on framework conditions. Framework conditions include the availability of skilled labour, infrastructure, universities, competition

[5] Although tax incentives and subsidies might reduce the need for external finance, they do not mitigate the underlying problem of information asymmetry

[6] Based on the finding of this report and OECD (2013) *OECD Science, Technology and Industry Scoreboard 2013,* OECD Publishing.

[7] A good that is both non-rival and non-excludable is known as a public good (Cornes and Sandler, 1986).

[8] Alternative ways to finance public goods are advertising and crowd-sourcing.

[9] World Bank and OECD: Innovation Policy Platform: Fiscal Measures. *Available at:* https://www.innovationpolicyplatform.org/ipp/filters/result-page?topic-filters=12308

environment, as well as the strength of intellectual property rights. Policies targeted to those elements can have a very strong impact on the type and amount of R&D performed by firms.

1.2 Main findings from the overview of R&D tax incentives

The overview of R&D tax incentive schemes presented in this report shows that 26 EU member states currently have some type of fiscal encouragement for R&D investments. The OECD countries selected for this study (Canada, USA, Japan, Israel and Norway) offer fiscal advantages for R&D activities as well. Most of the countries surveyed have more than one R&D tax incentive in place. The design and implementation of policy instruments varies substantially across countries – and sometimes within countries as well.

The majority of tax incentives apply to corporate income taxes, yet in eight countries benefit is (additionally) set against social contributions and/or wage taxes. R&D tax credits are the most popular type of R&D tax incentive (introduced in 21 countries), followed by enhanced allowances for expenditure on R&D (sixteen countries) and accelerated depreciation (thirteen countries). In the past years tax benefits for income from innovation, patents boxes, have also gained popularity: currently, eleven EU member states offer such an incentive.

In the past fifteen years R&D tax incentives that apply to the total R&D expenditure (volume-based schemes) have become considerably more common than tax benefits that apply only to the increment of R&D expenditure (incremental schemes). As of today, only seven countries offer incremental tax incentives in addition to volume-based, and in Ireland and the United States the 'incremental' part of the design is phasing out.

R&D tax incentives are frequently targeted to specific groups of firms. The most widespread form of targeting, is to offer a more generous tax advantage to SME's: currently ten countries have such a practice. In six countries the benefit is higher for young firms and in several countries the legal status of the applicant is important (in Canada, for example, foreign-owned companies receive a less generous tax reduction). In order to limit the government costs and indirectly provide more generous (marginal) support to smaller firms, five countries have the generosity of the scheme decreasing with the size of a firm's R&D expenditure. In addition, most countries put a ceiling on the amount that firms can receive. In terms of organization of the R&D tax incentives, most countries offer firms an online application procedure and a one-stop agency (one institution, where all relevant matters can be settled). Evaluations of the tax instruments have been carried out in fourteen countries, yet only in six countries they are embedded in the legal system.

1.3 Main findings from the literature survey

The report covers a large body of literature assessing the impact of R&D tax credits. The vast majority of studies surveyed concludes that R&D tax credits spur investment in R&D. The estimates of the size of this effect are widely diverging and not always comparable across methodologies. The wide range of results probably reflects differences in methodology as well as differences between countries and policies, but is difficult to disentangle those effects. Studies that are more rigorous econometrically and yield more precise estimates find that one euro of foregone tax revenue on R&D tax credits raises expenditure on R&D by less than one euro (Cornet and Vroomen, 2005; European Commission, 2008; Lokshin and Mohnen, 2012; Mulkay and Mairesse, 2013).

The impact of R&D tax credits on R&D expenditure is informative on the effectiveness of R&D tax credits, but this is only a part of the puzzle. A second piece of the puzzle is the answer to the question whether R&D tax credits make firms more innovative and productive. The impact of R&D tax incentives on innovation and productivity by firms receiving those benefits, however, is less studied. R&D tax incentives appear to have a positive impact on innovation, although none of the studies has used exogenous variation to verify the causality of the relation.

Payroll withholding tax credits may have an upward effect on the wages of R&D workers Cornet and Vroomen (2005) and Lokshin and Mohnen (2013). Goolsbee (1998) found the same effect for the total government expenditure on R&D in the United States. This is additional evidence of the effectiveness of tax credits: a rise in demand is expected to lead to higher prices in most markets.

The effects of R&D tax incentives vary across sub-groups of firms, with most studies focusing on firm size. The results seem to differ across countries, which makes it difficult to draw clear conclusions. In some of the countries analysed, SME's tend to respond more strongly to the support for R&D, while the reverse was found in other countries. It is not clear whether differences in outcomes are due to tax incentive characteristics, other country characteristics, methodology, or something else. There is some evidence that the impact for start-up firms can exceed the average impact, but in general, there is not much evidence on how effectiveness of tax incentives varies with firm age. There is a clear literature gap in identifying whether the impact differs across firms with different legal status.

Estimates of the social rate of return to R&D are variable and imprecise but tend to exceed estimates of the private rate of return to R&D (Hall *et al.*, 2009). This indicates that there is a scope for innovation policy to raise welfare. Recent evidence suggests that knowledge spillovers of large firms exceed those of small firms (2013). This finding provides an argument against targeting tax incentives towards SMEs. On the other hand, SMEs tend to respond more strongly to R&D tax incentives. This suggests that targeting on SMEs still could be efficient.

Social cost-benefit analyses for The Netherlands, Canada and Japan showed that R&D tax credits can have positive welfare effects but that this outcome is highly sensitive to assumptions (Parsons and Phillips, 2007; Russo, 2004; Ghosh, 2007; Mohnen and Lokshin, 2008; Cornet, 2001; Diao *et al.*, 1999).

The impact of R&D tax credits may be highly sensitive to their design and implementation. The different results found for SMEs across countries are indicative of this. However, evidence on the effects of design features is inconclusive for some features, while for evidence is lacking altogether for other features. An important aspect of R&D tax credits is whether they apply to incremental R&D expenditure or whether they are "volume-based". Both kinds of designs have been evaluated, and both of them have been found to result in additional R&D expenditure. The variation in estimates across studies is too large to be able to conclude that there is a statistically significant difference between the effectiveness of incremental and volume-based schemes.

Lester and Warda (2014) oppose the general perception that only volume-base R&D tax schemes result in dead-weight loss. They simulate different policy scenarios on different types of firms and find that even at low levels of growth the cost effectiveness of the two types of schemes will be the same.

Whether R&D tax incentive schemes targeted at cooperation between firms or public research institutes lead to higher additionality, is understudied. Research cooperation between competitor companies is shown to lead to collusive outcomes in the product market (Duso T. *et al.*, 2014).

A large body of literature has identified that multinational firms increasingly engage in profit-shifting activities in order to decrease the overall tax liabilities. Intangible assets, like patents, play an important role as they are relatively easy to move from one location to other. In addition, for large firms innovation often is an international activity: firms may perform R&D in one country, patent the product in another and commercialize it in a third one. Studies show that a strong negative relation persists between corporate income tax and the number of patents registered in a country. Patents with a higher potential profitability appear to be especially sensitive to corporate income taxes.

Patent boxes can result in large decreases in tax revenue for all governments engaging in such a policy (Griffith *et al.*, 2014). Furthermore, it is hard to make the argument why a patent box would reduce market failure caused by knowledge spillovers: patent boxes introduce a preferential rate for income from innovations that are already protected by IPR. The impact on innovation of patent boxes is difficult to evaluate empirically as tax planning and tax competition induce measurement error in innovation indicators.

Comparing the effectiveness of R&D tax incentives across countries is a challenging task. Most R&D tax incentives have not been evaluated quantitatively, making it impossible to compare them directly. When an evaluation study is available, it is difficult to compare the results with other evaluations as evaluation studies differ wildly in their methodology. Moreover, similar R&D tax incentives might have very different impacts due to differences in framework conditions.

1.4 Main findings on best practices

In the absence of comparable evidence on the performance of specific R&D tax incentives, more than 80 tax incentives in 31 countries[10] have been benchmarked. The benchmarking is based on twenty *principles of best practice*, which are divided over three categories: 1) scope of the instrument: how does the tax incentive work, which expenditures are eligible, 2) targeting: does the instrument target specific types of firms, explicitly or implicitly, and 3) organizational practice: how does the application procedure work and is the tax incentive evaluated?

One of the best practice principles proposed in this report is that volume-base R&D tax credits are preferred over incremental ones. Incremental R&D tax incentives may distort optimal investment planning and result in higher administrative and compliance costs. These higher costs of incremental schemes are probably not offset by a greater effectiveness of incremental schemes as recent simulations indicate - even for low levels of firm growth. The vast majority of instruments are volume-based.

Another principle proposed in this report is that tax incentives should only be aimed at R&D activities that are likely to contribute to the world-wide stock of knowledge, rather than support activities limited to advancement in firm's own state of expertise. The impact of a tax incentive on innovation will depend strongly on the strictness of its novelty requirement. Without any novelty requirement, a tax incentive could stimulate imitation, rather than innovation. Such a scheme could reduce innovation instead of promoting it. A number of R&D tax incentive schemes have strict novelty requirements (see Table 5.3 for an overview of novelty requirements across countries).

Tax incentives should ideally apply to those types of expenditures that bring about strong knowledge spillovers. Tax incentives based on the wage bill paid to researchers can be considered best practice in this context, for example because researchers move from one employer to another. A practical advantage of tax incentives for R&D wages

[10] Note that in total 33 countries were included in the analysis of the report. However, two EU countries- Estonia and Germany- do not offer R&D tax incentives. Thus, those two countries were not included in the benchmarking

is that they have lower administration and compliance costs. Tax credits for researcher wages can be found in The Netherlands and Belgium, amongst others (see Table 5.2 for an overview).

Young companies, rather than SMEs in general, are probably more likely to bring the innovations that challenge large incumbent firms. Targeting young companies can be considered a better practice than targeting SMEs. A scheme that explicitly targets young firms is the French Jeunes Entreprises Innovantes. An overview of all countries can be found in Figure 5.4.

As R&D expenditure may precede revenue generated by innovation by several years, it is good practice to provide a carry-over facility and an option to receive the benefit even in case a company is not profitable (cash refunds). Such features offer firms more flexibility and certainty for investment decisions. This is especially relevant for young companies that typically are not profitable in the first years of operations. While most of the R&D tax incentives analysed offer a carry forward facility, cash refunds are available only in nine countries (see full list in Table 5.5).

With respect to the organization of a tax incentive it is good practice to have a one-stop, online application procedure. This is already in place in majority of the countries. In addition, the time it takes for tax authorities to make a decision on eligible expenses should be as short as possible, not exceeding a year. Several countries have already introduced an option to receive an immediate refund for smaller companies, as these firms are typically more liquidity constrained.

Systematic evaluations are also recommended. High-quality firm-level data is indispensable for a rigorous quantitative evaluation and should be collected according to international standards. Currently, only few countries have frequent evaluations, for example, The Netherlands and France.

The scores of tax incentives on the twenty best practice principles are used to compute an overall index. The instrument that has the highest overall benchmarking score is the French tax credit for young innovative enterprises (Jeunes Entreprises Innovantes), due to high scores on scope and organizational practice. The Norwegian SkatteFUNN tax credit comes second, mainly because of its first place for organization. The third position is taken by the Accelerated amortization in Denmark, with high scores on targeting and organization.

Overall, the eighty R&D tax incentives show substantial heterogeneity in their designs and organizational practice. Tax credits distinguish themselves from enhanced allowances and facilities for accelerated depreciation primarily because of their higher score on scope. Patent boxes have the smallest average score on scope. The heterogeneity of practices not only is present between types of tax incentives; differences among schemes of the same type are also large.

Heterogeneity in the features of tax incentives is likely to reflect differences in country characteristics (like innovation systems and tax rates), but also within countries there is sometimes a large discrepancy between the highest ranked instrument and the instrument with the lowest rank. This suggests that there are substantial opportunities for improving R&D tax incentives across the European Union - in particular with respect to the organization and scope of the tax incentives.

1.5 Earlier surveys

Several reports and academic articles provide overviews of R&D tax incentives and their effectiveness.[11] Köhler et al. (2012) conclude that R&D tax incentives have a positive impact on R&D expenditure, although estimates vary substantially and mostly represent schemes that were in place in the 1980s and 1990s. They note that a positive impact is found for all types of R&D tax incentives and that volume-based incentives and R&D tax credits appear to have the largest effects on R&D expenditure. Köhler et al. indicate that the impact on outcomes other than R&D expenditure are less studied and little can be said about the long-run welfare effects of R&D tax incentives.

Köhler et al. make several policy recommendations: schemes should be differentiated by firm size or the amount of R&D expenditure (e.g., by introducing caps). This report surveys new evidence that questions the targeting of SMEs: Bloom et al. (2013) which suggest that large firms generate larger spillovers than small firms. Köhler et al. further propose that for firms that have used the the R&D tax scheme for some time, a lower rate should be applied.

Ientile and Mairesse (2009) also conclude that the impact of R&D tax credits on R&D investment is quite heterogenous, likely sensitive to the country analysed and methodology used. They noted that while the R&D tax incentives appear to be efficient in Norway and France, evaluations for Spain and The Netherlands provide less convincing results. They also encourage more research on the impact on second- and third-order effects, like impact on productivity, innovation outputs and the welfare effects. Ientile and Mairesse further suggest that a comparability between the studies should be enhanced through aligning on the addressed questions, methodologies used and ways the results are presented.

More technical surveys of the empirical evidence and methdologies used in the evaluations of R&D tax incentives are provided in Hall and Van Reenen (2000) and the European Commission (2008). Both explain the different approaches undertaken in the evaluations, their advantages and benefits. The survey by Hall and Van Reenen is the only one that gives a quantitative assessment of how much additional R&D expenditure is induced by R&D tax credits. They conclude that one dollar spent on R&D tax credits translates in about one additional dollar spent in private R&D. Based on evidence presented in more recent studies this report concludes that the impact of R&D tax credits probably is smaller.

The report of European Commission (2008) discusses the advantages and shortcomings of each evaluation method. They conclude that there is no one 'perfect' way how to assess the effectiveness of the schemes and that the evaluation is challenged by various data and methodological limitations. To increase our understanding about the impact of R&D tax incentive designs, comparability across studies should be promoted through exploiting similar data and methodologies.

Lokshin and Mohnen (2008) and Hall and Van Reenen (2000) note that measuring the bang-for-the-buck (BFTB) is important, but that this does not replace social cost-benefit analysis. Even if the BFTB lies below one, the scheme may still result in generating higher welfare due to the positive spillover effects.

[11]See Hall (Hall and Van Reenen, 2000), Ientile and Mairesse (2009), Köhler et al. (2012), Mohnen et al. (Mohnen and Lokshin, 2011), Parsons and Phillips (2007), Lester and Warda (2014), OECD (2013b), Deloitte (2014), and European Commission (2008).

OECD is providing overviews of R&D tax incentive schemes in OECD and selected other countries on a frequent basis. The most recent report that focuses on investment in knowledge capital, growth and innovation, concludes that R&D tax incentives are effective in promoting more R&D investment, but that the impact is sensitive to policy design and implementation (OECD, 2013b). For example, the positive impacts can be largely diminished, if schemes are changed frequently. Young firms can be supported by cash-refunds and carry-over provisions. Direct subsidies may be more beneficial for young firms since they usually need upfront funding to start a project. Incremental schemes are advocated by the OECD, as they result in lower government cost and dead-weight loss. In this report we do not find clear evidence favouring incremental schemes above volume-based schemes.

The OECD report criticizes the usage of patent boxes. They argue that firms can use patent boxes for profit-shifting operations and that it leads to tax competition between the countries. All this may result in overall lower welfare. The conclusion by the OECD is compatible with studies surveys in this report.

1.6 Outline

The remainder of this report is organized as follows. Chapter two reviews the evidence on the effects of R&D tax credits on R&D expenditure, innovation, productivity and welfare. It also compares R&D tax incentives with direct subsidies. Chapter 3 considers the relation between corporate taxation and the location of R&D activity and patents. Here, the effects of patent boxes are also discussed. In Chapter 4 challenges for future evaluation studies are discussed. An overview of R&D tax incentives in EU and selected OECD countries can be found in Chapter 5. In Chapter 6 principles for good practices regarding R&D tax incentives are discussed and both instruments and countries are ranked according to those principles. Chapter 7 concludes. For ten tax incentives, a detailed assessment is provided in the Annex on good practice cases (separate document). An overview and discussion of R&D tax incentives for each country can also be found in the Annex (separate document).

2 Impact of R&D tax credits and allowances

The empirical literature on the effectiveness of R&D tax incentives is concentrated on the impact of R&D tax credits on R&D expenditure. The reason for this probably is that R&D tax credits are the most prevalent R&D tax incentive and that its impact on R&D expenditure is much easier to identify than its impact on innovation and economic growth.

Nevertheless, there are plenty of challenges to overcome when studying the effect of R&D tax credits on R&D expenditure and as a consequence there is a wide range of estimation results to consider. The next sections will provide an in-depth discussion of this literature, in order to give the interested reader insight in which results are more probable.

2.1 Impact on R&D expenditure

The literature on the quantitative evaluation of R&D tax credits usually is divided into two strands. Both approaches estimate an equation that predicts R&D expenditure through different firm-, time- and location- specific factors. The two approaches broadly differ in the way the information about the presence of R&D tax incentives is introduced. The first approach assesses the response in a firm's R&D expenditure to changes in the user-cost of R&D capital. The user cost of capital can be defined as the 'actual costs' of R&D faced by firm, where an R&D tax credit is one of the determinants, next to the wage rate of researchers and the price of equipment (Hall and Van Reenen, 2000).

The coefficient that is usually estimated with this strategy is the elasticity of R&D expenditure with respect to the user cost of capital. For a tax credit to be effective in increasing R&D expenditure the expected sign of the elasticity is negative; 'other things being equal' a decrease in the costs of R&D is expected to lead to an increase in expenditure on R&D. We will refer to this estimation strategy as the "structural approach" because it relies on an explicit economic model.

Sometimes also estimates of "input additionality" are published, which are calculated after estimation using the user cost elasticity. Input additionality (or bang-for-the-buck, BFTB) is defined as the firm's R&D expenditure that can be attributed to the policy intervention relative to the size of the tax credit itself. If a firm spends every euro it saves on taxes on R&D, then input additionality is equal to one; if the firm spends ten percent more than it receives as a tax credit, input additionality is 1.1.

With the second approach, R&D expenditure is regressed directly on a variable that accounts for the presence or strength of the R&D tax credit. The estimated coefficient on the tax incentive usually can be directly interpreted as the input additionality of the R&D tax credit. We will refer to this estimation strategy as the "direct approach".

Besides the apparent differences in the interpretation of the estimated coefficients between the two approaches, there are other, more fundamental, differences. Each approach has its own set of assumptions on which the demand equation for R&D is based and each approach has its own econometric challenges. For these reasons, we present the results from the two approaches separately. We start by reviewing key studies, followed by a discussion of the wider literature.

2.1.1 Structural approach

The structural approach models R&D expenditure as a function of different firm-specific explanatory variables and a price index of R&D inputs - the user cost of R&D capital. In some studies R&D tax incentives are explicitly incorporated in the price index, whereas in other studies only more general factors like the wage rate for researchers are included (Hall and Van Reenen, 2000). If the input price index includes the firm's R&D tax incentive, then the effect of a change in the incentive can be directly calculated using the estimated coefficients and the data used for estimation. A complete incorporation of R&D tax policy into the user cost of R&D capital can be difficult when, for example, carry back and carry forward are possible.

If no information on R&D tax incentives has been included in the user cost of capital, measuring their effectiveness involves two steps. First, the elasticity of the user cost of R&D capital to R&D expenditure is measured. Second, the impact of an R&D tax incentive on R&D expenditure can be inferred from the estimation results and the calculated change in user costs of R&D capital due to the tax incentive.

The advantage of the structural approach is that it allows for a more complete understanding on how changes in tax incentives impact R&D expenditure since it is integrated with other R&D costs faced by firms. It also permits estimation of short and long run effects, where the short-run typically refers to one year and the long-run refers to five to fifteen years.

A difficulty of the structural approach is that the user cost is determined simultaneously with the R&D level. Depending on the context, there can be various reasons why the R&D level affects the user cost of R&D capital, such that the causality runs both ways. In particular, a number of R&D tax credit schemes share the characteristic that the size of the tax credit is dependent on the amount of R&D performed. The user cost of R&D capital thus increases with the level of R&D expenditure, which leads to potential underestimation of the effectiveness of the tax credit.

Lokshin and Mohnen (2012) avoid this endogeneity problem by using instrumental variable (IV) estimation techniques in a study of the Dutch payroll withholding tax credit (WBSO). On average, they find that a ten percent decrease in the user-cost of R&D capital induced by the tax credit leads to four percent more R&D capital in the short run (after one year) and six percent more in the long run (after fifteen years).

They also calculated the input additionality by simulating a removal in the incentive scheme using their estimates of the user cost of R&D capital elasticities. As firms need time to adjust their R&D capital to the new optimum, they will first reduce their R&D expenditure strongly and then slowly increase their investment levels until the new desired level of R&D capital has been reached. Over the first four years after the removal the input additionality was about one, while after fifteen years the additionality declined to 0.5 and was not statistically different from zero. The tax credit had a positive long-term impact on small firms, but not on larger companies.

Mulkay and Mairesse (2013) studied the R&D tax credit in France in the period between 2000 and 2007. They apply three different techniques (fixed effects, first-differences and GMM) and find a long-run elasticity of R&D capital with respect to the user cost of R&D capital of -0.2. This means that a decrease in the user cost of ten percent will induce a level of R&D capital that is two percent higher. In addition, they simulated the expected effects from the 2008 reform in the French incentive programme[12] and concluded that in the long-run the reform would stimulate R&D expenditure by twelve percent. This corresponds to a long-run input additionality of 0.7.

[12] French R&D tax credit (CIR) was incremental until 2003, when the volume based part was introduced alongside. It was then reformed to be fully volume based in 2008.

In an older paper Bloom et al. (2002) analyzed the impact of changes in R&D tax credits on R&D expenditure at the industry level for a panel of nine OECD countries[13]. They found that, on average, a ten percent decrease in the user cost of R&D capital increased the R&D capital stock by around one percent in the short run and ten percent in the long run.

Table 2.1 gives an overview of the estimated effects found in studies that use the structural approach. The negative estimates shown in this table imply a positive effect of R&D tax incentives on R&D expenditure. Although estimated elasticities range from -4.4 to -0.03, the more reliable studies (see below) tend to report elasticities between -0.6 and -0.1. The results obtained in the studies suggest that R&D tax incentives lead to an increase in the level R&D expenditure of firms with a long-run input additionality that probably lies below one (Lokshin and Mohnen (2012), Mulkay and Mairesse (2013)).

The long-run effects reported in Table 2.1 tend to be substantially larger than the short-run effects (i.e. long-run elasticities are smaller). The reason for this is that it takes time for firms to adjust their R&D capital stock to the new user cost. The relation between the (long-run) user cost of R&D capital elasticity and input additionality is not straightforward and requires a numerical simulation. The numerical simulation by Lokshin and Mohnen (2012) suggests an input additionality that lies below one in the long run given their long-run elasticity estimate of -0.63. Similarly, Mulkay and Mairesse (2013) find an long-run elasticity of -0.28 and conclude from a simulation of a policy reform that the input additionality of the new policy would be 0.7.

Table 2.1 also summarizes the methodological characteristics of studies. Studies using GMM tend to produce the largest estimated effects (typically elasticities smaller than minus one), while studies using a fixed effect estimator lead to the smallest effects (elasticities around -0.2).

Chapter 4 discusses reasons why estimates of effectiveness can be biased. Some of the studies could be substantially affected by one or more of these estimation problems, especially failure to take reverse causality into account and selection bias. Studies that adopt econometric strategies to avoid these problems include Lokshin and Mohnen (2012) and Mulkay and Mairesse (2013). In these studies, instrumental variable techniques are applied in a credible way, yielding robust results with small standard errors.

[13] The countries included: Australia, Canada, France, Germany, Italy, Japan, Spain, United Kingdom, and United States.

Table 2.1 Estimates of the user cost of R&D capital elasticity (negative estimate implies positive effect)

Study	Published[c]	Country	Period	Scheme	Obs. level	Method	Dependent variable	Mean result short-run	Mean result long-run
Baghana and Mohnen (2009)	yes	Quebec	1997-2003	incremental, volume	firm	OLS	log R&D level	-0.08	-0.12
Bloom et al. (2002)	yes	OECD	1979-1999	incremental, volume	industry	IV	log R&D level	-0.25	-0.97
Caiumi (2011)	no	Italy	1998-2005	Volume	firm	matching; GMM	log R&D level	-0.30	-0.60
Corchuelo, Martinez-Ros (2009)	no	Spain	1990-1998	incremental, volume	firm	selection model; IV	log R&D level	-1.09[a]	
Corchuelo, Martinez-Ros (2009)	no	Spain	2002	incremental, volume	firm	selection model; IV	log R&D level	-0.47[a]	
Dagenais et al. (1997)	no	Canada	1975-1992	Volume	firm	IV	log R&D level	-0.07[a]	
Harris et al. (2009)	yes	North. Ireland	1998-2003	Volume	firm	GMM	log R&D level	-0.53	-1.37
HMRC (2010)	no	United Kingdom	2003-2007	enhanced allowance, volume	firm	GMM	log R&D level	*Total:* -0.91[b] *SME scheme:* -2.32 *Large:* -2.41	*Total:* -2.60[b] *SME scheme:* -2.16 *Large:* -3.65
Koga (2003)	yes	Japan	1989-1999	incremental	firm	IV	log R&D level	-0.61[a]	
Lokshin and Mohnen (2012)	yes	Netherlands	1996-2004	volume	firm	IV	log R&D level	-0.38	-0.63
Mulkay and Mairesse (2003)	no	France	1982-1996	incremental	firm	fixed effects	log R&D level	-0.14	-0.05
Mulkay and Mairesse (2008)	no	France	1983-2002	incremental	firm	fixed effects	R&D intensity	-0.14	-0.28
Mulkay and Mairesse (2013)	yes	France	2000-2007	incremental, volume	firm	fixed effects; GMM	log R&D level		-0.16
Parisi and Sembenelli (2001)	no	Italy	1992-1997	volume	firm	Tobit, rand. eff.	log R&D level	-4.36[a]	
Poot et al. (2003)	no	Netherlands	1997-1998	volume	firm	OLS	log R&D level	-0.11	-1.12
Rao (2013)	no	United States	1981-1991	incremental	firm	IV	R&D intensity	-1.64	
Westmore (2013)	no	OECD	1983-2008	incremental, volume	country	OLS	log R&D level	-0.03	-0.88
Wilson (2009)	yes	United States	1981-2004	incremental	firm	OLS	log R&D level	-1.21	-2.18

[a] Short-run or long-run not specified; [b] Estimates that assumed endogenous user-cost elasticity; [c] Study has been published in peer-reviewed journal

2.1.2 Direct approach

The studies that follow the direct approach rely less on economic theory for identification of the impact of R&D tax credits than the structural approach. Usually, they explicitly compare the R&D expenditure of a 'treatment' group with that of a 'control' group. Studies differ primarily with regard to how those two groups are defined. Some studies simply compare firms that received and did not receive the R&D tax incentive (binary regression). Other studies use more elaborate identification strategies, like matching or difference-in-difference (DID).

Matching techniques first estimate a model that predicts the usage of tax incentives given firm characteristics. In a second step recipient companies are matched with non-recipient companies that share similar observable characteristics or have approximately the same probability ratio of being an R&D tax recipient firm. The effect of the tax incentive is then estimated by comparing the R&D performance between the matched companies.

Corchuelo and Martínez-Ros (2009) introduced such approach in their study on Spanish R&D tax credits. They find that that the impact was positive only for large firms and firms in high to medium technology sectors. Caiumi (2011) combined matching techniques and structural modelling to estimate the effects of R&D tax credits in Italy. She first analyzes the characteristics of firms using the tax credits and then matches beneficiary and non-beneficiary firms to compare the results obtained through a model introduced by Mulkay and Mairesse (2003). The estimated BFTB showed that 1 euro of tax foregone resulted in an additional 0.86 Euros spent of R&D.

By itself, matching techniques do not explain why some companies receive a tax incentive while other apparently similar companies do not. The (unknown) reason for receiving treatment might also have consequences for firm performance. For example, a talented entrepreneur might run an innovative company, but might also be more inclined to apply for a tax credit. Matching techniques by themselves do not correct for this self-selection of firms into the treatment group.

A strategy that exploits natural experiments in order to account for self-selection is the difference-in-differences (DID) estimator. It focuses on firms that had very similar R&D behaviour (and company characteristics) before an introduction or change of a policy that affected only part of this group of firms. If unaffected firms (the control group) spend less on R&D than the firms that were affected by the policy change (the treatment group), it can be concluded that the (change in) policy is effective.

DID was applied by Cornet and Vroomen (2005) to the reform of the Dutch WBSO program in 2001. This reform involved the introduction of a special tax credit for start-up firms and an extension of the first tax-credit bracket. They use these policy changes and the specific discontinuous design of the instrument to define the control and treatment groups.

They found that the introduction of the start-up scheme induced an increase in the R&D wage bill of between ten and twenty percent. They also calculated the BFTB that showed that on average a euro spent in terms of foregone tax revenue induced between 50 to 80 eurocents of additional labour expenditure. The extension of the tax bracket, however, showed that every tax euro lost resulted in only 10 to 20 eurocent spent on labour costs (Cornet and Vroomen, 2005).

Even though studies that estimate the effect of R&D tax credits directly use a wide variety of methods, the literature seems to agree that R&D tax credits tend to increase R&D expenditure. Table 2.2 gives an overview of these studies. The magnitude of the estimated effects is difficult to compare. We can only compare studies that report an estimate of the BFTB. Among these studies the BFTB range from 0.15 to 3.5. The highest estimates are found by Dumont (2013). The outcomes of this study are probably biased upwards because of an endogeneity problem in the regression specification as the level of R&D expenditure is regressed on the level of the benefit received.

Various econometric techniques have been used for direct estimation of the effect of R&D tax credits. Matching techniques clearly are the most popular. Most of these studies, however, do not exploit exogenous variation and are therefore sensitive to the selection bias discussed earlier.[14] The study by Cornet and Vroomen (2005) is a good (and rare) example of a study that uses difference-in-difference with properly defined control group.

Taken together, both structural and direct studies provide evidence that R&D tax incentives induce more R&D expenditure. However, the studies that better correct for econometric problems, including endogeneity bias and selection effects, tend to find an input additionality below one (Lokshin and Mohnen (2012), Mulkay and Mairesse (2013), Cornet and Vroomen (2005)).

A more formal assessment of literature requires a meta analysis. The tentative meta analysis by Ientile and Mairesse (2009) shows that studies with low standard errors have an input additionality below one (see Figure 2 in their paper). The meta analysis by Castellacci and Lie (2013) find a corrected elasticity of the user costs of R&D capital of -0.23 and a corrected additionality ratio of 0.03. Meta analysis by Gaillard-Ladinska, Non and Straathof (2014) shows that reported estimates are often inflated substantially due to publication selection bias[15]. When accounting for this bias, the effect on R&D expenditure is positive but modest.

[14] See also Chapter 4.

[15] Stanley (2008) define Publication selection bias or the "file drawer problem" as "the consequence of choosing research papers for the statistical significance of their findings". Publication bias also applies to individual estimation results when they are not reported by researchers because of their statistical insignificance or magnitude.

Table 2.2 Direct estimates of treatment effects of R&D tax incentives

Study	Published[b]	Country	Period	Scheme	Obs. level	Method	Dep. variable	Measure	Mean result
Aralica et al. (2013)	yes	Croatia	2007-2009	volume	firm	matching		Treatment effect	0.14
Aralica et al. (2011)	no	Croatia	2007-2009	volume	firm	survey/tax record analysis	R&D level	BFTB	1.19
Corchuelo and Martinez-Ros (2009)	no	Spain	2002	mixed	firm	matching	log R&D level	Treatment effect	0.66
Cornet and Vroomen (2005)	no	Netherlands	1994-2004	volume	firm	diff-in-diff, first diff.	log R&D wages	BFTB	0.15 startups: 0.65
De Jong et al. (2007)	no	Netherlands	2001-2005	volume	firm	fixed effects	log R&D wages	BFTB	1.72
Duguet (2012)	yes	France	1993-2003	incremental	firm	binary; matching	R&D growth	BFTB	1
Dumont (2013)	yes	Belgium	2001-2009	volume	firm	panel, selection model	log R&D level	BFTB	research coop.: 2.22 young innov.: 0.79 PhD: 3.50 master: 0.82
Hægeland and Moen (2007a)	no	Norway	1993-2005	volume	firm	diff-in-diff	log R&D level	Treatment effect	1.34
Hallépée and Garcia (2012) [a]	no	France	2002-2005	volume	firm	matching	employment	Treatment effect	>1
Ho (2006)	no	United States	1963-1999	incremental	firm	matching; diff-in-diff	log R&D level	Treatment effect	0.07
Kasahara et al. (2013)	yes	Japan	2000-2003	volume	firm	selection model; GMM	log R&D level	Elasticity pooled	1.58
Klassen et al. (2004)	yes	United States, Canada	1991-1997	incremental, volume	firm	fixed effects	log R&D level	Elasticity pooled	1.81
Lee (2011)	yes	Japan, Canada, Korea, Taiwan, China, India	1997	incremental, volume	firm	GMM, IV	R&D intensity	Elasticity pooled	0.18
Lhuillery et al. (2013)	no	France	1993-2009	volume	firm	matching	R&D level	Treatment effect	small firms: -1.10 medium firms: -0.71 large firms: 0.50
Verhoeven et al. (2012)	no	Netherlands	2006-2010	volume	firm	GMM	log R&D wages	BFTB	1.77
Yohei (2011)	no	Japan	2006-2009	mixed	firm	matching	R&D intensity	Treatment effect	1.25

[a] standard errors and econometric specifications are not published; [b] Study has been published in peer-reviewed journal

2.1.3 Incremental and volume-based schemes

Tax credits are implemented in two different ways: volume-based or incremental. The volume-based scheme applies to all qualified R&D expenditure, while an incremental scheme only applies to increases in R&D expenditure. In the latter case, the base amount on which the increment is calculated is a firm's average expenditure either in some fixed period of time (for example between 2010 and 2012) or during the past few years (for example the last 3 years).

As incremental schemes only apply to increases in a firm's R&D activity, one might expect that the additional R&D expenditure induced by one euro of tax credit is larger for incremental schemes than for volume-based schemes (Lokshin and Mohnen 2012). This line of reasoning does not take into account that firms consider the net present value of a tax credit rather than the tax credit they receive for the current year when they decide on investment in R&D. Firms that did not perform R&D before will be indifferent between an incremental and volume-based scheme as long as long as the expected net present value of the tax credit per extra euro spend on R&D today is the same. Incremental tax credits will only save government expenses by decreasing the effective tax credit for firms that performed R&D at the time the scheme was introduced.

Table 2.3 Mean user cost elasticities for volume-based and incremental schemes

Scheme	Short-run elasticity	Long-run elasticity	Number of studies
	mean (sd)	mean (sd)	
Volume	-0.90	-1.48	8
	(0.78)	(1.06)	
Incremental	-0.50	-0.84	3
	(0.62)	(1.17)	
All	-0.78	-1.29	11
	(0.73)	(1.07)	
Note: the standard deviation across studies is given in parenthesis.			

Table 2.3 summarizes estimates of the elasticity of R&D expenditure to the user cost of R&D capital for both incremental and volume-based schemes. The mean elasticity for volume-based schemes is smaller than the mean elasticity found for incremental schemes, both in the short and long run. The difference in means is not statistically significant as standard deviation of estimates across studies is large. In particular, if we would remove the study by HMRC (2010) then the mean for volume-based schemes exceeds the mean for incremental schemes. Altogether, there does not seem to be systematic evidence that elasticities for incremental schemes differ from those for volume-based schemes.

There does not appear to be a consensus in the literature on this topic either. In a testimony for the United States Senate Committee on Finance, the OECD concluded that incremental schemes have an input additionality of above one, while volume-based schemes have an additionality of below one (OECD, 2011). Also this conclusion was based on a small number of studies of different schemes. Lester and Warda (2014) arrive at a different conclusion. They show that for firms with a modest autonomous growth in R&D expenditure, the cost-effectiveness of incremental schemes is similar to volume-based schemes. As incremental schemes are more costly to administer, they conclude that "the case for incremental credits is far from compelling".

2.1.4 Impact on wages

The literature on input additionality discussed above evaluates the impact of R&D tax incentives on R&D expenditure. When R&D expenditure increases this can be due to more R&D but it can also be caused by an increase in prices of R&D inputs. Several studies have been concerned with such a price effects, focusing on the question by how much an increase in R&D spending is in part a reflection of an increase of the wages for R&D personnel.

First to identify this phenomenon was Goolsbee (1998), who analyzed the total government expenditure on R&D in the United States during the period from 1968 to 1994. He found that a rise in R&D expenditures by ten percent results in an immediate rise in the wages of researchers by one percent and by another two percent in the following four years. He concluded that by ignoring this effect, the additionality of public support for R&D may be overestimated by 30% to 50%. This effect was measured during a period with substantial variation on government expenditure, which might explain part of the size of the effect.

More recently, Lokshin and Mohnen (2013) estimated that the elasticity between the effective rate of the Dutch payroll tax withholding R&D tax credit and average R&D wage is 0.2 in the long run. Such a positive relation was also found for the Norwegian SkatteFunn Scheme, where for every 100.000 Kroner per R&D man-year that a firm received through the tax credit, each R&D worker received about 33.000 as a wage increase (Hægeland and Møen, 2007a). They also noted that this effect is largely driven by small and medium-sized companies, where the subsidy of 100.000 Kroner resulted in an average wage increase of 53.000 Kroner.

Dumont (2013) confirmed the relationship between R&D tax credits and R&D wages for Belgium. One euro spent on a subsidy or partial exemption from advance payment is associated with a wage rise ranging from 0.15 to 0.45 euros.

As most of the evidence discussed above applies to payroll withholding tax credits, it might be that the impact on wages of corporate income tax credits is different. As corporate income tax credits usually apply to both capital expenditure and researcher wages, it could be that researcher wages are less strongly affected by this type of tax credit and that the reverse applies for the prices of other types of R&D-inputs.

The price effect of R&D tax incentives is not an undesirable feature, but a normal reaction in a market where demand becomes larger. The supply of specialized researchers and equipment needed to meet the rise in demand is not available overnight. Higher wages for R&D personnel will induce a larger supply of high-skilled workers, but will take years before supply is fully adjusted.

Changes in R&D input prices are not taken into account with existing estimates of the effectiveness of tax credits, such that estimates of input additionality and the elasticity of the user cost of R&D capital discussed above overestimate the impact on R&D activity. The impact on wages is not unique to R&D tax incentives, but applies government expenditure on R&D in general.

2.1.5 Behavioural impact

Do R&D tax incentives motivate firms to start doing R&D or change their organizational practices in ways are more related with psychological factors than with cost-benefit analysis? Ernst (2011), analyzing a set of European firms, found that R&D tax incentives motivate firms to start investing in R&D. Others confirm the positive impact only among specific sub-populations of firms. Caiumi (2011) showed that medium-sized, start-ups and credit-constrained firms in Italy were more likely to invest in R&D in the presence of the R&D tax credit. In the evaluation of Norwegian

SkatteFUNN, the authors indicated that the strongest impact on behaviour was for firms without or with limited previous R&D activity (Hægeland and Møen, 2007).

2.1.6 Impact heterogeneity

Even though R&D tax incentives are generic in nature, they tend to have distinct impacts on different types of companies. The most widely studied firm characteristic in this context is firm size. In most countries small (and liquidity constrained) firms tend to respond more strongly to the R&D tax incentives (Kasahara et al. (2013) and Yohei (2011) for Japan; Lokshin and Mohnen (2012), for The Netherlands; Baghana and Mohnen (2009) for Canada; Bloom et al. (2002) for OECD countries).

The opposite conclusion can be drawn for Spain (Corchuelo and Martínez-Ros, 2009), Belgium (Dumont, 2013) and France (Lhuillery *et al.*, 2013). Here large firms tend to be more responsive to R&D tax incentives than small firms. For Italy the evidence is mixed. Caiumi (2010) finds that the impact on SMEs is stronger, while Cerulli and Poti (2012) conclude that large firms are more responsive.

To complicate the overall picture, Streicher, Schibany and Gretzmacher (2004) found for Austria that small and large firms had higher input additionality than medium-sized enterprises. In contrast again, Lokshin and Mohnen (2007) found that the strongest impact on R&D expenditure was for medium-sized firms. They did not find an additional effect for large firms.

A partial explanation for these contrasting findings is that in Spain and Italy small firms were less likely to know (and apply) for tax incentives (Corchuelo and Martínez-Ros, 2009; Caiumi, 2010).

The apparent disagreement amongst the studies on which type of firm is most responsive to R&D tax incentives, could reflect the importance of differences in the implementation and design of policy instruments as well as variation in general framework conditions. Also, failure to separate the effects on young firms from the effects on small firms could provide an explanation for these paradoxical findings: the proportion of innovative firms is likely to be larger among start-ups than the proportion of innovators among firms that are older but did not manage to grow.

Targeting on young firms might be more efficient than targeting in small firms. However, few papers contain evidence on whether the impact of tax credits is related to firm age. Cornet and Vroomen (2005) evaluate the impact of the introduction of a more generous treatment for start-up firms in the Dutch payroll tax withholding credit (WBSO). They found that the start-up scheme induced between 50 to 80 eurocents of additional labour expenditure, which was substantially larger than the impact of the WBSO for medium-sized and large companies (10 to 20 eurocents).

The impact of R&D tax credits might vary across sectors. Few studies, however, report estimates per industry. Deriving industry effects from differences in samples across studies is risky and requires a meta-analysis to be able to take into account other study-specific characteristics. Castellacci and Lie (2013) perform such an analysis and find that high-tech industries tend to be less responsive. Their conclusion, however, hinges on a very small number of observations on high-tech industries.

It seems probable that the effectiveness of R&D tax will also vary across countries: this and other reports show that the differences in organization across countries can be substantial. In addition, countries have different economic characteristics and have different innovation systems. Harris et al. (2009), for example, study the effectiveness of an R&D tax credit for Northern Ireland, which can be considered a disadvantaged region within the United Kingdom. They conclude that the tax credit would have to be increased substantially in order to have a substantial impact on regional production and that such an increase would not be very cost-effective.

An assessment of differences across countries would require that a study be repeated in several countries. We have not found such a study. Also, we number of studies that are highly comparable in terms methodology is too small to be able to make a distinction between differences in results that are caused by methodology from differences caused by country characteristics. Another complication is that evaluations have only been performed for a small number of countries. Countries with poorly designed and implemented R&D tax incentives tend not to have been evaluated econometrically.

2.2 Impact on innovation and productivity

2.2.1 Innovation

R&D expenditure is positively related to innovation (see Danguy *et al.*, 2009 for a review), but this does not automatically imply that R&D tax incentives that raise R&D expenditure will also stimulate innovation. Several econometric studies have focused on the question whether R&D tax incentives indeed also induce firms to innovate more. The estimation strategies that have been followed are similar to the strategies found in the literature focusing on direct estimation of the impact on R&D expenditure. Innovation or another output indicator is regressed on an indicator for the R&D tax incentive and firm-, time-, and location-specific characteristics.

Even though the effect of R&D tax incentives on innovation and other second-order, or "output", effects can be estimated using the same approaches as with R&D expenditure, there are additional complications. First, one needs to define the 'innovative output', which can be very broad set of outcomes. Most studies use patent applications, introduction or sales of new products. Second, the impact on output will take longer to materialize and might arrive more gradually than the impact on R&D expenditure. Third, the output of an R&D project is fundamentally uncertain: the intended innovation might not materialize or might not be a commercial success. These complications imply that the risk of biased or imprecise estimation results is larger than for studies focusing on R&D expenditure.

Czarnitzki et al. (2011) examines the effect of R&D tax credits on innovation by Canadian manufacturing firms for the period from 1997 to 1999. They used a non-parametric matching technique to compare firms that used the tax credit with firms that did not use it. As the authors acknowledge this approach is sensitive to selection bias on unobserved characteristics. Canadian firms Tax credit recipients realize a higher number of product innovations, as well as increased sales shares of new and improved products. The study finds that firms receiving a tax credit have a higher probability to introduce new products, both to the national Canadian market and to the world market.

Ernst and Spengel (2011) use firm-level data from multiple European countries. They combine financial data on firms with firm-level patent data in order to test how a firm's patenting activity responds to a change in R&D tax incentives and corporate tax burdens. R&D tax incentives are found to have a positive effect on patenting. The statutory corporate income tax rate has a negative impact on patenting.

Westmore (2013) shows that R&D tax incentives are positively related with patenting in a country-level analysis of 19 OECD states. He estimated that a decrease in the B-index[16] of 0.05 raises the number of patents per capita by around 2.5 percent. Other

[16] The B-index is defined as the net present value of after-tax costs of spending one euro on R&D divided by one minus the corporate income tax rate. If the after-tax

evidence on a positive relation between R&D tax incentives and innovation is found by Aralica (2013) for Croatia, by De Jong and Verhoeven (2007) for The Netherlands.

In contrast, Ernst et al. (2014) finds that R&D tax credits and tax allowances have a negative impact on patent quality[17] for European corporations between 1998 and 2007. This last study could indicate that while R&D tax incentives appear to be effective in increasing incremental innovations, they might not result in more radical innovations. For patent boxes they find a positive impact on the quality of patents.

Overall, studies on the effectiveness of R&D tax incentives tend to find a positive impact on innovation. Although the literature is not very large, this outcome appears to be relatively robust as various methods and data sources lead to similar conclusions. None of the studies reviewed has used exogenous variation to verify the causality of the relation.

2.2.2 Productivity

R&D can improve the efficiency of firms through process and product innovation. Process innovation can lead to more efficient production processes, while product innovation can increase the demand for the company's products. Doraszelski and Jaumandreu (2013) conclude that R&D is a major determinant of variation in output productivity across firms and for the evolution of productivity of individual firms over time.

The direct evidence on the impact of R&D tax incentives on productivity is limited. Caiumi (2011) found that the Italian R&D tax incentive program did overall raise the productivity of firms. The impact is, however, very heterogeneous across less and more productive firms. Caiumi notes that the impact was stronger for firms on the lower bound of the productivity distribution.

Hallépée and Garcia (2012) present many results on the effects of the French R&D tax incentive for Jeunes Entreprises Innovantes (JEI). Using matching techniques they find an 8.4 percentage point increase in employment for treated firms, an increase of survival rate of firms, higher wages, and an input additionality exceeding one. The reliability of these findings, however, is unclear as estimation results and econometric specifications are not documented.

Is the impact on productivity of R&D induced by tax incentives smaller than the impact of other R&D? Firms will pursue the most profitable R&D projects before they engage on less promising ones, such that the marginal returns to R&D are decreasing. This has implications for the expected impact of R&D tax incentives on productivity: additional R&D expenditure induced by the incentive is likely to be less productive than the firm's average (Ientile and Mairesse, 2009). Empirical evidence does not seem to support this hypothesis. Cappelen et al. (2007) show that R&D induced by the Norwegian R&D tax incentives contributes in the same way to productivity as other R&D.

costs per euro R&D expenditure are equal to the income tax rate, the B-index is equal to one. The interpretation of this case is that R&D expenditure is not treated differently from other costs. A B-index smaller than one indicates that R&D expenditure is treated more favourably than other costs.

[17] Measured as combined index of forward citations, family size and the number of technical fields that serves as an indicator for the product's potential profitability

2.3 Tax incentives versus direct subsidies

2.3.1 What policy instruments do firms choose?

Even when a firm is eligible for both a subsidy and a tax credit, it might not apply for both with the same probability. The take-up rates for subsidies and R&D tax incentives might differ with the type of firms (Busom *et al.*, 2012; Duguet, 2012; Corchuelo and Martinez-Ros, 2009). In Spain small and financially constrained firms were more likely to use R&D subsidies than tax incentives. SMEs that had innovative products (and that used IPR to protect them) were more likely to use R&D tax incentives than subsidies (Busom et al., 2012). Corchuelo and Martínez-Ros (2009) showed that in Spain R&D tax incentives and subsidies also are complements since firms that receive a grant are more likely to also apply for an R&D tax incentive.

In France the opposite seems to be true. Duguet (2012) noted that in France R&D tax credit recipients tend to be smaller and have a higher R&D intensity in comparison to companies using R&D subsidies. Whether firms apply for a subsidy or tax incentive probably is largely determined by the way these instruments are designed and implemented.

2.3.2 Effectiveness of direct subsidies

There is a long standing discussion on whether direct subsidies generate more R&D than tax incentives, or vice versa. Governments should in principle be able to target these projects with the highest marginal social rates of return via direct subsidies (David *et al.*, 2000). With tax incentives this is more difficult, since the general nature of tax incentives allows firms to expand their R&D activity in areas with high private rates of return (in the short-run). On the other hand, firms might lobby successfully for subsidies that are in their interest, possibly diverting subsidies in ways not conducive to innovation - an argument made by Hall and Van Reenen (2000).

The empirical literature comparing the effectiveness of grants and tax incentives directly is limited in size. A firm level study of Norwegian firms suggests that tax credits appeared to have a slightly larger effect than direct support measures (Hægeland and Møen, 2007b). Empirical findings from a panel of 19 OECD countries indicate that direct support seems to have a larger impact than (volume-based) R&D tax incentives (Westmore, 2013). Instrument design and implementation might be more important determinants of additionality than whether the instrument is a direct subsidy or a tax incentive.

David et al. (2000) review the literature on the effectiveness of public expenditure on R&D in general. They conclude that findings in the literature are ambiguous and that more sound econometric studies are needed to find a definitive answer to this question. A recent survey by Zuniga-Vicente et al. (2012) confirms the heterogeneity in outcomes also for recent studies. They report that 71 studies report complementarity between public subsidies and private R&D, while 23 studies point towards crowding out. 24 studies did not find a significant effect. The majority of studies (sixty percent) points to effectiveness of R&D subsidies.

In a meta-analysis of this literature García-Quevedo (2004) could not explain the heterogeneity in results by methodological differences in studies. Zuniga-Vicente et al. (2012) arrive at the same conclusion. This means that the heterogeneity in the effectiveness of R&D subsidies probably is due to differences in policy instruments and country characteristics.

The outcomes of recent studies fit within the pattern that instrument and country characteristics are likely to be crucial for effectiveness. Takalo, Tanayama, and

Toivanen (2013) estimate the expected welfare effects of Finnish R&D subsidies. They find that the social rate of return on the subsidy program is between thirty and fifty percent. The authors note that spillover effects and application costs vary widely between firms and the spillover effects are somewhat smaller than the private benefits accruing to subsidized firms. Czarnitzki and Lopes-Bento (2013) reject the hypothesis that Flemish R&D subsidies completely crowds out investment in private R&D.

Another recent study does not find clear evidence on the effectiveness of R&D subsidies. Cerulli and Poti (2012) find that Italian public subsidies hardly affect R&D intensity and R&D per employee, while the evidence for an impact on R&D expenditure is mixed.

2.3.3 Multiple treatments

Frequently, firms will be able to use both subsidies and tax incentives, but studies that evaluate the returns to R&D tax incentives rarely take into account multiple treatments. Ignoring multiple treatments might lead to biases in estimation results as other evidence suggests that there are notable differences between firms that use only one and firms that use more measures (Corchuelo and Martinez-Ros, 2009; Dumont, 2013).

Dumont found that firms who used just one of the policy tools had the highest additional effect. Bérubé and Mohnen (2009) find that Canadian firms benefiting from both tax incentives and direct grants introduced more new products to the market than firms that only benefited from R&D tax incentives. The limited empirical evidence indicates that interactions between different policy measures probably exist. The importance and direction of interaction effects depends off course on the national setting and the characteristics of specific instruments, but policy makers should be aware of unintended side effects when multiple treatments are provided to firms.

2.4 General welfare effects

2.4.1 Evidence on private and social rates of return to R&D

Even if the evidence that R&D tax incentives lead to more innovation would be clear, this does not automatically imply that R&D tax incentives are good policy. Direct effectiveness of tax incentives are just a first requirement for having a positive impact on welfare.

Another requirement is that firms actually innovate insufficiently from society's perspective i.e. that markets fail. In a review of the literature Hall et al. (2009) find that, although estimates of the social rate of return to R&D largely apply to the manufacturing sector and are "variable and imprecisely measured in many cases", they tend to exceed estimates of the private rate of return to R&D. They do not offer a quantitative estimate of the relationship, indicating that "there is nothing like a single private "rate of return" that is close to a cost of R&D capital". Parsons and Phillips (2007) report a specific number: the median social rate of return found in the literature they surveyed is 56 percent.

A recent study by Bloom et al. (2013) on firms in the United States between 1981 and 2001 confirms the conclusion that the social rate of return exceeds the private rate. They show that the social returns to R&D are at least twice as high as private returns. Depending on the methodological approach, the private returns aggregated across all firms are between 21 percent and 39 percent. While social returns vary between 55 percent and 59 percent.[18]

The gap between social and private returns to R&D is more profound for large firms than small firms. They divide firms in quartiles according to their size and find that the private returns of largest firms are around 21 percent, while social around 67 percent. For smallest firms, private returns similarly make 21 percent, while social are only around 27 percent. Large firms are active in technological fields in which many other firms are active as well. Small firms tend to focus to 'niche' markets and generate less knowledge spillovers (Bloom *et al.*, 2013).

2.4.2 Social cost-benefit analysis

It is informative to know how much R&D a euro spent on R&D tax incentives induces, but it is only part of the analysis required to draw conclusions on their social impact. Even when input additionality is below one, the social rate of return on R&D could be such that the net welfare gain of the policy is positive.

Whether an R&D tax incentive should be introduced or continued or not, requires the social benefits of the incentive exceeding the social costs. Only few authors have attempted such a complete assessment and their results are rather inconclusive, reflecting the intrinsic methodological difficulties. One example of social cost-benefit analysis is by Parsons and Phillips (2007) who analyzed the Canadian tax credit system. They evaluated the program, taking into account four aspects: (1) relationship between firm R&D expenditure and the R&D price; (2) the spillover effects from additional R&D expenditure; (3) the costs of the increased tax burden; and (4) the administrative and compliance costs of the tax credit. They conclude that the tax incentive has a positive welfare effect of eleven cents for every dollar spent in terms of lost tax revenue. However, they also show that the results are highly sensitive to model specification.

A social cost-benefit analysis by Cornet (2001) shows that the welfare effects of Dutch WBSO program are rather unclear and can be negative, depending on the model specification and the target group analyzed. Another social cost-benefit analysis for WBSO was performed by Lokshin and Mohnen (2009). They showed that even if the BFTB falls below one, the general welfare effect can still be positive due to spillover effects. Following Parsons and Phillips (2007), they estimate the net welfare effect and conclude that the Dutch WBSO program resulted in a 16 percent net welfare gain.

They also simulate several marginal policy changes and show that a 2 percent increase in first bracket rate would result in an increased R&D expenditure for small firms by 2.5 percent in the short-run and then would decline to around 1.3% in the long-run. The effect for large companies would be very minimal. Atkeson and Burstein (2011) analyzed the long run impact of a change in innovation policies. They identified that the federal R&D support was positively associated with innovative activity. However, they also find very strong negative relation between corporate income tax and innovation, additionally demonstrating that in case of too high corporate tax system the positive impacts of the R&D support diminishes.

2.4.3 Aggregate impact and stability

A few studies focused on the aggregate impact of (changes in R&D tax incentives). Westmore (2013), for example, showed that an increase in the generosity of R&D tax

[18] Private and social returns are defined as the return to a marginal United States dollar spent on R&D.

incentives by six percent - reflecting an increase of the benefit level in the United States to the level of Japan in 2008 - would increase aggregate R&D expenditure by around six percent in the long run.

In a recent OECD study, Bravo-Biosca et al. (2013) conclude that more generous R&D fiscal support is correlated with lower productivity and on aggregate lower employment growth. The only subgroup whose employment growth is positively related with more generous R&D tax incentives is incumbent firms. More generous R&D tax incentives were strongly negatively related with high-growth firms.

They also compared the impact of R&D tax benefits in the most and least R&D-intensive industries (computers and construction, respectively) in the countries with the most and least generous R&D tax credits (Spain and Italy, respectively). More generous benefits turned out to be positively associated with growth of companies operating in less R&D-intensive sectors. The results of Bravo-Biosca et al. indicate that the studied R&D tax incentives are supporting incumbent firms and raise barriers for innovative entrants.

Decisions on R&D are characterized by long-term commitment and investments. In such setting, the predictability of a policy instrument is crucial for its effectiveness. Westmore (2013) demonstrated for the panel of OECD countries that the beneficial effects of R&D tax credits were greatly reduced when an instrument was modified frequently.

3 Corporate taxation and the location of R&D activity and patents

3.1 Sensitivity of location to corporate taxation

A large body of literature has documented that differences in corporate taxes are important for the location of a firm's capital and profits (see a survey of empirical literature in Devereux and Maffini (2007), De Mooij and Ederveen (2003).[19] Countries offering lower corporate tax rates attract more capital and profits from multinationals. De Mooij and Ederveen (2003) performed a meta-analysis of studies on the impact of corporate taxes. They find that a decrease by one percentage point in the host-country tax rate leads to an increase of foreign direct investment by around 3.3 percent. Devereux and Maffini (2007) do not quantify the relationship between tax rates and the location of capital and profit since the results varied widely across countries and periods, as well as across methodologies.

Several studies identified that R&D activities and related income are especially sensitive to corporate taxes (Desai *et al.*, 2006; Stöwhase, 2002; Grubert and Slemrod, 1998). (Grubert, 2003) studied parent companies from the United States and their manufacturing subsidiaries and found that R&D related intangible assets were responsible for around half of the income that was shifted from high-tax to low-tax countries. Transactions among the affiliations of a firm are hard to tax properly as it is difficult to assess the price of services within a firm. The reason for this is that intangible property transferred within a firm is very firm-specific. A comparable transfer may not exist in the market, and its price is therefore not observed (see for more discussion on this and firms' profit-shifting strategies in Griffith et al. (2014), Ernst and Spengel (2011), Dischinger and Riedel (2011) and OECD (2013a; 2013a).

Bloom and Griffith (2001) affirm the 'footloose' nature of R&D activities by looking at a panel of European countries. Within a multinational group, R&D activities are not only sensitive to domestic user-cost but also to one at foreign affiliates, shifting to places with lower user-cost[20]. For states in the United States, Wilson (2009) finds that R&D tax incentives attract R&D from other states, while the overall amount of R&D is not affected. He concludes that incentives are "a zero-sum game among states". Dischinger and Riedel (2011) provide evidence that European multinational companies do involve in profit-shifting activities. They show that the intangible asset investment flows to those affiliates that, relative to other subsidiaries, have lower tax rate. Quantitatively, "a 1 percentage point decrease in the average tax rate differential with the other subsidiaries[21] translates in 1.7% increase in the stock of intangible assets in the lower-tax subsidiary" (Dischinger and Riedel, 2011).

The location of patent applications by European corporations is also responsive to corporate income tax rates (OECD, 2013b). Karkinsky and Riedel (2012) estimated that an increase of one percentage point in the corporate tax rate results in a fall in the number of patent applications of 3.5 to 3.8 percent. Griffith et al. (2014) analyze variations in tax rates across countries. They find that the share of patent locations in Luxembourg is most responsive to tax rates, while in Germany they are least

[19] Earlier surveys of the impact of taxes on the location of FDI include Devereux and Griffith (2002), Newlon (2000) and Hines (1997, 1999).

[20] they instrument user-cost with corporate tax rate

[21] "Average tax difference to all other affiliates calculated as: corporate tax rate of the considered subsidiary minus the unweighted average corporate tax rate of all other group" (Dischinger and Riedel, 2011)

affected.[22] A one percentage point increase in the corporate tax rate in Luxembourg leads to a 3.9 percent decrease in the share of patent applications, while in Germany this is only 0.5 percent.

The number of patents registered in a country is not necessarily indicative of a country's innovativeness for two reasons. First, patents are very heterogeneous in terms of the novelty and value of the underlying invention. Scherer et al. (2000) show that roughly ten percent of inventions are responsible for the majority of the total economic value of innovation. Harhoff et al. (1999) find that the commercial value of patents differs extensively and also identifies the skewness of the value distribution.

Patents are also heterogeneous with respect to their sensitivity to corporate taxation. The valuable patents were found to be the more sensitive to corporate tax rates than patents that are not valuable. Ernst et al. (2014) find a negative relation between the corporate tax rate and the patent quality. Similarly, Griffith et al. (2014) show that the elasticity between the corporate tax and number of patent applications is largest for patents with higher potential profitability.

The second reason why the number of patents registered in a country does not reflect its innovativeness is that the country from which a patent is applied for not necessarily the country (or countries) where the invention originated. For patents applications at the European Patent Office (EPO) the country of the inventor also is not a reliable source as applicants are not legally required to inform the EPO about the addresses of inventors. Especially larger companies might apply for patents from countries other than those where they perform their R&D as they tend to have a subsidiaries dedicated to IP-issues and because it is sometimes more advantageous to apply for a patent from a country with a patent box (see below).

Corporate income taxes, of course, are not the only determinant of location of intangible assets. The strength of intellectual property rights, market size and degree of technological innovativeness[23] were also found to play an important role. All these factors are found relate positively with the share of patent applications in most of the subgroups analysed (Griffith *et al.*, 2014).

The possibilities for tax planning not only lead to a loss of tax revenue, but might also distort competition. Large firms tend to have broader opportunities to shift operations across different affiliates. Mutti and Grubert (2009) document indirect evidence that American parent companies more frequently earned royalty income in foreign low-tax affiliates. Small firms usually do not have the same possibility for tax planning as large firms do, which puts them at a disadvantage and might reduce their incentives for innovation.

Tax planning might also distort markets as some industries are more responsive to differences in corporate tax rates and rules than others. Griffith et al. (2014) conclude that electrical and engineering industries are more sensitive to changes in corporate tax than the chemical industry.

It could be that tax planning has a smaller impact in Europe than in the United States. European firms appear to be more reluctant to shift the profits from headquarters than American firms. Dischinger et al. (2014) found that the profits of European multinationals tend to concentrate in their headquarters. They showed that the volume of profit-shifting from a higher-tax subsidiary to a lower-tax headquarter was

[22]The analyzed countries included: Belgium, Denmark, Finland, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland, United Kindom and United States.

around seventy percent larger than the volume running from a high-tax headquarter to a low-tax subsidiary. This is consistent with the results of a study by Dischinger and Riedel (2011), which shows that the headquarters of European multinational firms are around thirty percent more profitable than their subsidiaries. This gap in profitability is, nevertheless, decreasing over time.

In part, European companies could be more reluctant to shift profits due to controlled foreign company (CFC)[24] rules. Various countries have implemented these rules in order to restrain the scope of profit shifting to tax havens. Bohm et al. (2012) found that CFC rules indeed limit the extent of profit-shifting and reduce the probability of patent relocation. As barriers to exit a country, also imply barriers to entry, CFC rules might make a country less attractive for foreign investment - also in R&D.

3.2 Patent boxes

A patent box is a tax incentive that offers a reduced corporate income tax rate for income derived from patents (it is called a box because there is a box to tick on the tax form). For most countries patent boxes are a relatively new scheme. So far a range of countries have adopted patent boxes, amongst them the United States, the United Kingdom, Belgium, Spain, Portugal, France, Ireland, the Netherlands, Luxemburg, Malta and Hungary.

Patent boxes are a distinct category of R&D tax incentives because they offer a large scope for tax planning by firms. They are also part of the strategy of at least some countries to increase tax revenues from foreign companies. Especially for companies with many patents, it can be very difficult to assess what part of a company's income is derived from which patent. This leaves much room for companies and governments to bargain on how much tax has to be paid.

The rationale for patent boxes as a means to stimulate innovation seems to be absent as it is not clear which market failures patent boxes address. Once patented, an invention is protected from imitation, such that firms no longer have a disincentive to innovate. It is not clear why especially innovations for which clear property rights are defined should receive a tax incentive. By subsidizing inventions that do not need a subsidy, patent boxes would induce inventions that are difficult to patent (and therefore might have high spillovers) relatively less attractive.

In the European context it has been discussed whether such special tax regimes could mainly benefit highly mobile businesses without triggering significant additional R&D activity. In the spring of 2014 the European Commission has probed into those schemes and requested information from several member states to analyze the true potential of patent boxes.[25]

Griffith et al. (2014) have performed simulations of how the introduction of patent boxes in Benelux countries and United Kingdom would change the registered origin of patents. After the introduction of patent boxes in Benelux countries, all three countries would experience a substantial increase in the share of new patents, in particular for patents with higher expected payoffs. Without a patent box, the United Kingdom would see a decrease in the share of new patents. After the United Kingdom would have introduced a patent box as well, its share of new patents rises at the expense of the Benelux countries.

[24] CFC rules that are implemented in sever "high-tax" countries to limit the income shifting from their residence country to affiliates in low-tax countries

[25] Press release: http://europa.eu/rapid/press-release_IP-14-309_en.htm

Regardless of the increase in the number of new patents registered domestically, all four countries would face a substantial net tax loss. Belgium and Luxembourg see a decrease of seventy percent, the United Kingdom sixty percent and The Netherlands fifty percent.

Evers et al. (2014) analyze the interaction between input-related R&D tax incentives and patent boxes in twelve EU member states. They point out that enhanced allowances of R&D expenditure that are applied to the normal tax in combination with a patent box that offers a reduced rate, can lead to negative effective average tax rates. This has the effect of providing a subsidy to unprofitable projects.

These results are consistent with the observation that in some countries firms can use the patent box regardless of the country in which the underlying R&D has been performed. Depending on the specific tax rules of countries, profits induced by an R&D tax credit in one country might be taxed in another country through a patent box. This does not make the R&D tax credit less effective as long as its goal is to compensate firms for knowledge spillovers.

Patent boxes seem more likely to relocate corporate income than to stimulate innovation. Unfortunately, tax planning and tax competition also complicate the possibilities for evaluation of the effectiveness of patent boxes with respect to innovation.

4 Challenges for evaluation

Despite the sizable literature on the effectiveness of R&D tax incentives, two broad challenges for researchers remain. A first challenge is to make evaluation studies more reliable by more use of natural and social experiments for identifying the impact of tax policies. In the absence of experiments, more use can be made of quasi-experimental methods like difference-in-difference. Most of the suggestions listed below have been made earlier. In particular, a report prepared by Expert Group on R&D Tax Incentives Evaluation contains a number of insights on how innovation policy can be evaluated reliably (European Commission, 2008).

A second challenge for the literature on the evaluation of R&D tax incentives is that many relevant topics are unstudied. First, almost all studies are on the effect of tax credits on expenditure. There are hardly any studies on other R&D tax instruments. Second, only very few studies consider the impact of R&D tax incentives on firm performance or beyond.

4.1 Challenge 1: methodology

The golden standard for policy evaluation compares the actual behaviour of a firm experiencing a tax incentive with the counterfactual situation in which the firm would not have had this incentive. Such a setting can be simulated using a social experiment, where R&D tax incentives are randomly allocated to firms. The causal effect of the policy is then captured by the differences in R&D performance between the recipients (the treatment group), and the non-recipients (the control group).

A similar strategy exploits unintended randomization of tax incentives given to firms. This is called a natural experiment. Natural experiments usually do not lead to an unbiased randomization of treatment with tax incentives, but still can be useful to assess the causal effect.

Due to the generic nature of the R&D tax incentives, which gives very little (if any) scope for randomization, social experiments are not available for assessing the effectiveness of these incentives. Natural experiments that lead to well-defined control groups are not common. R&D tax incentives are therefore assessed through various other techniques that seek to account for methodological challenges that arise from not being able to construct a random control group.

4.1.1 Reverse causality

One methodological challenge is how to separate the causal effect of tax incentives on the behaviour of firm’s from causal relations that run in the opposite direction. For example, most studies assume that tax incentive policy is independent from the R&D performance of firms. However, R&D tax incentives can be introduced or amended precisely because of an underinvestment in R&D. This introduces correlation between tax incentive adoption and firm performance. A similar case occurs when R&D intensive countries are more inclined to spend money on innovation policy.

Similarly, the characteristics of an R&D tax incentive instrument itself introduce a correlation between the size of the incentive and the amount of R&D. For example, firms with a large expenditure on R&D might benefit relatively less than firms that spend less. Simply regressing R&D expenditures on firm characteristics and the tax incentive measure will underestimate the causal effect of the incentive.

In response to these problems with reverse causality, researchers have applied instrumental variable (IV) techniques that use a third variable which is informative on the causal relation of interest. However, this approach comes at the costs of less precise estimates and the inherent difficulties in finding a suitable instrumental variable (Hall and Van Reenen, 2000). The use of invalid instruments will increase, rather than decrease, estimation bias. In practice, studies using IV regression analysis are very heterogeneous in terms of their reliability.

4.1.2 Selection bias

Usually any firm that carries out R&D is eligible for R&D tax incentives. This implies that the group of firms using a tax incentive is very different from the group of firms that do not use that tax incentive. Comparing the performance of these two groups of companies will lead to biased estimates of the effect of the incentive: the difference in performance is not just driven by treatment with the tax incentive, but also by differences in company characteristics. This type of bias is known as selection bias: firms self-select into the treatment group, based on their characteristics.

There are various strategies to reduce selection bias. One approach is to control for the differences between the two groups using control variables. Examples of this approach are regression analysis and matching estimators. The assumption underlying these methods is that all relevant differences between firms are observed. These measures are still sensitive to selection bias when part of the differences between firms is unobserved.

A second approach to selection problems is to compare firms that just meet the criteria for eligibility with firms that do not satisfy the criteria, but only barely. This is called a regression discontinuity design (RDD). RDD is only applicable when information on eligibility is available and if the eligibility criteria are continuous, which often is not the case for tax incentives. RDD only allows for estimation of the causal effect for firms that are barely eligible. So far this method has not been applied in the context of R&D tax incentives.[26]

A third strategy is to compare the performance of firms before an R&D tax incentive is introduced with their performance afterwards. This can be done with a simple panel regression. If one also includes firms that do not receive treatment in the sample while controlling for firm level time trends, then this approach is know as difference-in-difference (DID). A drawback of this strategy is that it is sensitive to other (unobserved) events taking place in the sample period that affect the treatment group in a different way than the control group.

4.1.3 Adjustment costs

R&D processes are characterized by high-adjustment costs (Hall *et al.*, 1986; Lach and Schankerman, 1989). As a consequence, the effect from a change in the cost of R&D due to a tax incentive might take several years to reveal itself. Researchers that only consider the short term impact of a change in R&D tax incentives are likely to underestimate the overall impact of the policy change. Another issue is that when studying the long-term impact, many other events will have occurred since the policy change. This will make it more difficult to get a precise estimate of the impact.

4.1.4 Re-labelling and changes in input prices

Introduction of R&D tax incentives can induce firms to re-label already existing activities to be defined as R&D expenditure. Re-labelling might be completely appropriate: before the policy change, some firms might have had no reason to be

[26] The DID study by Cornet and Vroomen (2005) has some characteristics of an RDD as some of the control groups are “close” to the treatment group in terms of their size.

very precise about which activities can be classified as R&D and only after the policy change they start to care about this. Re-labelling itself does not change the firm's R&D activities, but time-series on R&D expenditure might show a sudden increase around the moment of the policy change.

Another response to the introduction of an R&D tax incentive is that the demand for the inputs of the R&D process increases. This increase in demand for researchers, lab equipment, etc. is not likely to be met by a proportional increase in supply as these inputs tend to be highly specialized. Especially in the short term, a new or more generous R&D tax incentive might therefore lead to higher input prices, including higher wages for researchers. R&D expenditure might increase in the short term, while R&D activities might lag behind as the supply of research inputs has to adapt.[27]

Re-labelling and changes in input prices could lead to overestimation of the impact of R&D tax incentives in the short-run. Accounting for long-term effects of R&D tax incentives is essential for understanding their overall impact.

4.1.5 Multiple treatments

Usually R&D tax incentives are not the only policy instrument targeted to innovation support. This makes it difficult for the policy evaluator to separate the impact of the R&D tax incentive from the impact of the other instruments. In particular, there are three issues: First, not all subsidies and tax incentives are observable in firm level data. Second, many firms will benefit from multiple instruments, which makes it more difficult to define control groups. Third, there can be interactions between R&D tax incentives and other policy instruments. Probably only well-designed social experiments are robust to these three problems.

4.1.6 Publication bias

Several meta studies have found strong indications of publication bias in papers analyzing the effects of R&D tax incentives (Castellacci and Lie, 2013; Ientile and Mairesse, 2009). This means that researchers tend to report only significant results. Especially researchers using less precise estimation methods or more noisy data are likely to report only large effect of R&D tax incentives. Meta analysis can help to uncover the true effect by correcting for publication bias.

4.2 Challenge 2: gaps in the literature

The focus of the literature is primarily on the impact of R&D tax credits on R&D expenditure. The impact on innovation, productivity and other aspects of firm performance is hardly studied. Also very few studies are devoted to the aggregate impact of R&D tax incentives and the performance of the economy.

The emphasis of the literature on the impact of tax credits on expenditure is well-grounded. Tax credits are the most popular tax incentive aimed at promoting innovation and if they do not induce more R&D spending to start with, they will not lead to more economic growth. However, there is a lack of evidence on other types of incentives and outcomes. In particular, researchers may consider the following gaps for future studies:

[27] If the introduction of an R&D tax leaves input prices unaffected, this can be considered an indication that the incentive will not be effective in the long-run either - unless the supply of all R&D inputs is perfectly elastic (which is improbable in general).

- Studies on the impact of tax incentives on R&D expenditure do not take into account that R&D input prices (notably the wages of researchers) can change in response to the tax incentives. This can lead to overestimation of their effectiveness.
- It is hardly studied whether tax incentives result in more innovation and how different types of innovation are affected (European Commission, 2008).
- Evidence on the social return to R&D tax incentives is almost non-existent.
- There is little knowledge about the impact of tax incentives of firm behaviour.
- The particular design features of an instrument and the way it is implemented remain outside the scope of most studies, but could be decisive for their impact.
- Very few studies take into account both direct subsidies and tax incentives at the same time, while multiple treatments are very common.
- It is not clear what the effect of firm age is on the impact of R&D tax incentives. In particular, start-ups should be considered separately from other SMEs. Do R&D tax incentives stimulate the entry of new innovative firms?
- Evidence is also lacking on the effect of R&D tax credits on attracting R&D activities from abroad. The same holds for its effect on extramural R&D in cooperation with other firms or public research institutes. Whether the company’s legal status matters for the impact of R&D tax credits has also not been researched.
- Natural and social experiments are almost never used. The number of studies employing quasi-experimental identification strategies is small. These strategies can be combined with the structural modelling, but to our knowledge this has not been done.

Most of the studies focus on R&D tax credits. Evidence is lacking for other types of popular R&D tax incentives, enhanced allowances and accelerated depreciation. The few studies on patent boxes do not provide evidence that firms become more innovative.

5 R&D tax incentives in the EU and selected OECD countries

The vast majority of countries included in this study[28] provide a favourable tax treatment of R&D expenditures.[29] At the moment of writing, only two out of the thirty-three countries analysed- Estonia and Germany- do not offer any tax incentive for R&D activities.

Countries have introduced the R&D tax incentives at different points in time and have shaped them in various ways. Even for such a generic policy instrument, the specific design, type and number of R&D tax incentives differ substantially across countries. These differences can be divided into three main categories:

1) scope of the policy, including the type of R&D tax incentive and costs covered
2) targeting of specific groups of firms, according to their size, age, region, etc.
3) organization, including administrative practices and generosity

We discuss each of these categories and present an overview of the practices in EU member states and selected OECD countries.

5.1 Scope

The scope of an R&D tax incentive defines how the instrument works conceptually: how the incentive is applied and what type of expenditure and income qualify. R&D tax incentives can be applied in at least four ways: as a tax credit, as an enhanced allowance, by allowing accelerated depreciation, and through reduced rates (patent boxes, for example). The incentive can be "volume-based" and apply to all R&D activity or it can be "incremental" and only apply to new R&D activity. The tax benefit can refer to different sorts of R&D expenditures. Usually, an R&D tax incentive applies to specific inputs that are used in R&D processes (incentive base) and requires some degree of novelty for the intended outcome (requirement of novelty).

5.1.1 Type of R&D tax incentive

Different approaches coexist in the way countries shape R&D tax incentives. Every scheme might have some particularities, but broadly four approaches can be distinguished: tax credits, enhanced allowances, accelerated depreciation and reduced rates (see Figure 5.1 for a brief description of each type).

[28]Austria, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, the United Kingdom, and the United States.

[29] The data in this chapter is collected from official national government sources, the OECD (http://www.oecd.org/sti/rd-tax-stats.htm), and ERAWATCH (http://erawatch.jrc.ec.europa.eu/). Detailed information on sources is provided in the Annex with country studies.

Figure 5.1 Description of different types of R&D tax incentives

Tax credits (R&D expenditure)	• Tax credit decreases the corporate income tax rate a firm has to pay • Rate can be applied to either corporate tax, payroll tax paid for R&D workers or personal income in case the incentive is targeted to self-employed
Enhanced allowances (R&D expenditure)	• An enhanced allowance effectively decreases the base amount that is taxed by allowing to 'inflate' the R&D expenditure base • Example: if R&D expenditure is EUR 100 and the rate of enhanced allowance 1.5 then the total R&D expenditure will be increased to EUR 150. This will decrease the base of taxable income.
Accelerated depreciation (R&D expenditure)	• Accelerated depreciation scheme permits to depreciate the purchased fixed assets at higher rates in the first years of the asset's life. This allows, therefore, to decrease the overall taxable income in the specific periods.
Reduced corporate tax rate (IP income)	• Reduced corporate tax rate on intellectual property income ("Patent Box") are an outcome related incentive • It reduces the corporate income that firms pay on commercialization of innovative products that are protected by intellectual property (IP) rights

Table 5.1 gives an overview of which tax incentives are used in which country. While some countries have only one type of instrument, several others use a mix of different types. Tax credits are the most widely used tax incentive (in 21 countries), but also enhanced allowances (in 16 countries) and accelerated depreciations (in 13 countries) are used in a substantial number of countries[30]. Patent boxes are a relatively new policy instrument, which has been introduced in eleven countries: first the Benelux states, followed by United Kingdom and others.

[30] Note that various countries have more than one type of R&D tax incentive

Table 5.1 Popularity of R&D tax incentive instruments

Countries	Tax credits	Enhanced allowance	Accelerated depreciation	Patent Box
Austria	x			
Belgium	x		x	x
Bulgaria	x		x	
Canada	x		x	
Croatia		x		
Cyprus		x		x
Czech Republic	x[a]	x		
Denmark	x	x	x	
Estonia				
Finland		x	x	
France	x			x
Germany				
Greece		x		x
Hungary		x		x
Ireland	x			
Israel	x[a]	x	x	
Italy	x		x	
Japan	x	x	x	
Latvia		x		
Lithuania		x	x	
Luxembourg				x
Malta	x			x
Netherlands	x	x		x
Norway	x			
Poland	x[a]	x		
Portugal	x			x
Romania		x	x	
Slovak Republic	x			
Slovenia		x	x	
Spain	x			x
Sweden	x			
United Kingdom	x	x	x	x
United States	x		x	

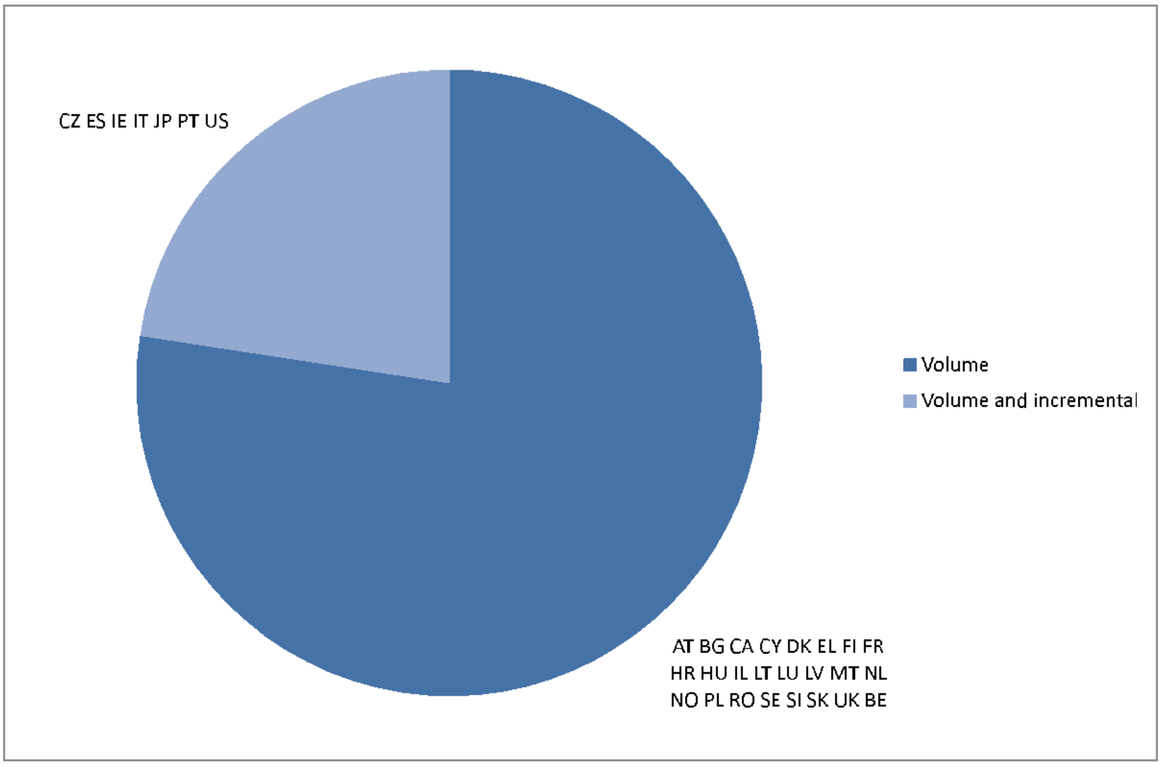
[a]Reduced corporate income tax rate

5.1.2 Incremental and volume-based schemes

Another aspect of the design of R&D tax incentives is the way their base is calculated. There are two approaches: a volume-based approach that applies to all qualified R&D expenditures and an incremental approach that only applies to the incremental part of R&D expenditure. The base amount on which the increment is calculated is an average amount that the firm had in either some specified period of time (e.g., between 2010-2012) or some specified number of (previous) years (e.g., last three years).

Currently, almost all countries have volume-based R&D tax incentives (see Figure 3.1.). Some countries have moved from incremental to volume-based schemes, one such example being France which moved to a fully volume-based scheme in 2008. Several countries operate both incremental and volume-based schemes (Belgium, Czech Republic, Spain, Ireland, Japan, Portugal and the United States). These schemes usually work as volume-based up till some threshold, after which an incremental scheme applies. Italy is the only European country in our sample that currently has only an incremental scheme.

Figure 5.2 Use of incremental and volume-based schemes across countries



Note: Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see annex with country fiches for more details)

5.1.3 Incentive base

R&D tax incentives also differ by the nature of the incentive base. In particular, some of the schemes are related to the income generated by R&D rather than its costs. R&D tax incentives that are based on costs can be targeted to different expenditure sub-categories. They are as follows:

- *R&D costs:* this category includes a variety of eligible expenditures. Some countries limit the type of costs and expenditures that qualify as R&D expenditures to machinery and equipment. Other countries restrict the qualifying expenditures to R&D costs that are carried out domestically.
- R&D wages: incentive is based on wage bill tax (payroll-withholding tax)
- *IP expenditures:* this category includes the costs and expenditure for acquiring patents, investments in intangible assets, or the purchase of new technologies
- *R&D and IP expenditures*: this is a combination of the first two categories
- *Discretionary:* a limited number of countries provide lower corporate tax rates for qualified R&D firms as such
- *IP income: incentive is applied to profits gained from commercialization of products that are protected by intellectual property rights*

Table 5.2 shows that most countries have incentive schemes that apply to R&D costs (23 countries), followed by R&D and IP income (12 countries). Three countries (Bulgaria, Czech Republic, and Israel) provide a reduced corporate tax rate for those firms that obtain the status of being an "R&D firm". Incentives based on IP income (mostly patent boxes) are in place in twelve countries.

The category R&D costs and expenditures can be divided into different sub-categories. For instance, in some countries only R&D wages are eligible costs, while other countries employ a much broader definition including buildings and overhead costs. Table 5.3 provides an overview of eligible costs at a more detailed level. Most countries (24) include wages in eligible expenses. In 18 countries also machinery is included and in 12- buildings. Prototyping costs are in eligible only in France, which has a special scheme that is targeted to such activities.

Table 5.2 Incentive bases used across countries

Country[c]	R&D costs	Wages	R&D, IP costs	IP costs	IP income	Discretionary
Austria	x					
Belgium		x	x		x	
Bulgaria	x			x		x
Canada	x	x				
Croatia			x			
Cyprus				x	x	
Czech Republic			x			x
Denmark	x			x		
Finland	x	x				
France		x	x		x	x
Greece	x				x	
Hungary	x	x			x	
Ireland	x		x			
Israel	x					x
Italy	x	x	x			
Japan	x					
Latvia		x	x[b]			
Lithuania	x					
Luxembourg					x	
Malta	x			x	x	
Netherlands	x	x			x	
Norway	x					
Poland	x		x		x[a]	
Portugal	x				x	
Romania	x					
Slovak Republic	x					
Slovenia	x					
Spain	x	x	x		x	
Sweden		x				
United Kingdom	x				x	
United States	x					

[a]Entities having R&D Centre status can deduct up to 20 percent of R&D revenues from tax base
[b]To be phased out
[c]Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

Table 5.3 Detailed incentive base across countries

Country[a]	Buildings	Machinery equipment	Wages	Overhead	R&D services	Consumables	Depreciation	Outsourced services	Prototypes
Austria	x	x	x	x					
Belgium	x	x	x				x		
Bulgaria	x	x							
Canada		x	x	x					
Croatia	x	x	x	x			x		
Cyprus									
Czech Republic			x				x		
Denmark		x	x		x	x			
Finland	x	x	x						
France			x		x	x	x		x
Greece									
Hungary			x		x	x	x	x	
Ireland	x	x	x	x	x	x	x	x	
Israel	x	x							
Italy		x	x						
Japan	x		x	x			x		
Latvia			x	x				x	
Lithuania			x	x					
Luxembourg									
Malta	x	x	x					x	
Netherlands	x	x	x	x		x			
Norway		x	x		x	x		x	
Poland	x	x	x						
Portugal		x	x		x	x			
Romania			x	x			x		
Slovak Republic									
Slovenia		x			x				
Spain		x	x		x	x			
Sweden			x						
United Kingdom	x	x	x		x	x		x	
United States			x		x	x			

[a]Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

5.1.4 Tax base

The benefit can be set against different tax liabilities. The most popular one is corporate income that is present in schemes in all countries, except for Sweden (see Table 5.4). A number of countries have R&D tax incentives also for personal income, which benefits micro-enterprises (Austria, Canada, France, Luxembourg, Netherlands and Slovenia). Sweden and France have tax incentives that are based on social security contributions and Belgium, Canada, Finland, Hungary, and Netherlands have tax schemes that are set against wage tax.

Table 5.4 Tax bases used across countries

Country[a]	Corporate income	Personal income	Wage tax	Social security
Austria	x	x	x	
Belgium	x			x
Bulgaria	x			
Canada	x	x	x	x
Croatia	x			
Cyprus	x			
Czech Republic	x			
Denmark	x			
Finland	x			x
France	x	x	x	
Greece	x			
Hungary	x			x
Ireland	x			
Israel	x			
Italy	x			
Japan	x			
Latvia	x			
Lithuania	x			
Luxembourg	x	x	x	
Malta	x			
Netherlands	x	x		x
Norway	x			
Poland	x			
Portugal	x			
Romania	x			
Slovak Republic	x			
Slovenia	x	x		
Spain	x			
Sweden				
United Kingdom	x			
United States	x			

[a]Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

5.1.5 Novelty of R&D outcome

Innovation is essentially about bringing new ideas to the market. If the purpose of R&D tax incentives is to foster innovation, it is not only relevant what type of R&D costs are eligible, but also whether R&D is primarily intended for true innovation or primarily for learning from other firms. In the strictest sense, the 'market' is the global arena. Countries have been somewhat looser on defining the size of this 'market'.

Four types of novelty requirements were encountered: (1) new to the world; (2) new to the country; (3) new to the product market; (4) and new to the firm. Figure **5.3** gives an overview of the novelty requirements per country.[31] The most stringent one - "new to the world"- is used in thirteen countries. This novelty requirement is also the norm formulated in the Frascati Manual: "The basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned." p. 34 (OECD, 2002).[32]
A less strict definition- "new to the country"- is used for a different scheme in France and in Japan. It is also the condition for novelty used by the United States Patent and Trademark Office (USPTO).

The most widely used novelty requirement "new to the firm" is used in thirteen countries. In contrast to more stringent requirements, this definition is easier to administer but reduces the focus of the instrument, such that a larger budget will be needed.

Figure 5.3 Definition of novelty for R&D tax incentives across countries

New to the world	New to the country	New to the firm	Ambiguous
•Belgium •Canada •France •Lithuania •Poland •Portugal •Romania •Slovenia •Spain •Sweden •United Kingdom •Croatia •Czech Republic	•France •Japan	•Austria •Denmark •Finland •Ireland •Italy •Japan •Latvia •Malta •Netherlands •Norway •Poland •Slovak Republic •United States	•Bulgaria •Greece •Hungary •Israel

Note: (a) Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details); (b) Countries may have different novelty requirements for different schemes

[31] Note that all tables and figures in this chapter show results per country, while the underlying observations are at the country/instrument level. This implies that a country could be listed in different rows, if different tax incentives in that country have different characteristics.
[32] Many patent offices, including the European Patent Office (EPO), use a similar novelty condition for patentability.

The definition of novelty used will have implications for the expected impact of an R&D tax incentive. If R&D is targeted to products that are new to the world, the incentive promotes pure innovation. If new to the country is sufficient, then the incentive also stimulates imitation from abroad. Finally, if there is hardly any novelty requirement, also domestic imitation is encouraged, having a risk to provide disincentives for firms to invest in radical innovations. The category 'ambiguous' contains those countries, for which the definition was ambiguous, unclear and/or not available.

5.2 Targeting

5.2.1 Explicit targeting

Beyond generic design characteristics that are relevant to all firms, R&D tax schemes can be shaped in a way to address particular target groups. This focus is usually part of more general policy goals or reflects the government's view on parts of economy needing extra support and/or having the strongest innovative activities. The scope and type of targeting can, therefore, depend on the specific policy issue at hand.

Targeting can be defined over different aspects that are usually overlapping to specify a very particular target group. One starting point is to define the beneficiary subjects that can either include all legal entities or specify a particular group (e.g., limited companies and co-operatives, self-employed, entities having an R&D status, and others).

SMEs and especially start-up companies may face increased difficulties in attracting finance that is needed to invest in R&D activities. Many countries try to alleviate these capital market imperfections by offering a preferential tax treatment to SMEs (France, Greece, Hungary, among others) and/or young start-up companies (Belgium, France, Netherlands, among others).

Similarly, tax incentives can have a geographical focus that can be determined by the central government (the case of Greece, Israel and Poland) or by regional authorities (Canada, United States and Spain).

Figure 5.4 Targeting of schemes across countries

Size
- France
- Greece
- Hungary
- Japan
- Malta
- Norway
- Poland
- Portugal
- United Kingdom
- United States

Age
- Belgium
- France
- Israel
- Netherlands
- Portugal
- United States

Legal status
- Austria
- Bulgaria
- Canada
- Czech Republic
- Finland
- Malta
- Netherlands
- Poland
- Slovenia
- Sweden

Region
- Canada
- Greece
- Israel
- Poland
- Spain
- United States

Field of activity / type of technology
- Belgium
- Bulgaria
- Canada
- Greece
- Israel
- United States

Note: Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

Some tax instruments are designed to promote R&D in specific industries that are considered either to be of strategic importance or face increased challenges. In some cases, it proves to be very hard to find a clear-cut definition of a specific industry or sector. In some countries R&D tax incentives have been tied to certain types of technologies (for example environmentally friendly technologies in Belgium) or fields of R&D (for example biotechnology and nanotechnology in Israel) that are indirectly associated to the specific industries. See Figure 5.4 for an overview of targeting in countries analysed.

According to EU Competition Law R&D tax incentives may constitute State aid. In principle, State aid is forbidden by the EC Treaty. However, in some cases where market failures exists, State aid will be considered compatible with the common market under specified conditions. State aid for R&D and innovation (R&D&I) is such an example and the framework for State aid for R&D&I and the provisions under the Block Exemption Regulations describe the conditions under which State aid is allowed.

5.2.2 Implicit targeting

Brackets and ceilings

Instead of explicitly targeting special groups of firms, countries implement tax brackets with different rates (see summary of implicit targeting in Table 5.5). All countries that have different tax brackets apply more generous deduction rates for expenditures below a certain amount. De facto, this makes schemes more generous for smaller firms with lower R&D expenditures. Such brackets are introduced in four countries (Canada, France, The Netherlands and the United States). Another way to limit the benefits for large firms is to put a ceiling on the amount that firms can claim, which allows governments to limit their costs. Most countries have adapted maximum deductions on one or more of their R&D tax incentives.

Carry back, carry forward and cash refunds

Small and startup firms often lack taxable income on which the tax-cut would apply, making it impossible to fully benefit from most R&D tax incentives (OECD, 2010). Thus, the provision to carry back and forward the expenditure, together with an option to receive the tax benefit in a form of cash refunds in case of losses, can be used as another type of indirect targeting.

Carry back and carry forward are not available for all R&D tax incentive schemes. For instance, with a payroll withholding tax credit a carry back, carry forward, or cash refund is implausible. Carry-over provisions are introduced in most of the countries studied. Cash refunds are less widespread and have been introduced only in nine countries.

Table 5.5 Implicit targeting

Country[e]	Brackets	Ceilings	Carry back (CB)	Carry forward (CF)	Cash refunds
Austria		x			
Belgium		x		indefinite	x
Bulgaria				x	
Canada	x	x	3 years	20 years[a]	x
Croatia		x		5 years	x
Cyprus					
Czech Republic				3 years	
Denmark		x		x	x
Finland		x		10 years	
France	x	x		3 years	x
Greece				x	
Hungary		x			
Ireland			1 year	indefinite	x
Israel		x		5 years	
Italy		x			
Japan	x	x			
Latvia				indefinite	
Lithuania		x		indefinite	
Luxembourg					
Malta		x			
Netherlands	x	x	1 or 3 years[d]	9 years	
Norway		x			x
Poland		x		3 years[b]	
Portugal		x		8 years[c]	
Romania		x			
Slovak Republic		x			
Slovenia		x		5 years	
Spain		x		18 years	x
Sweden					
United Kingdom		x		indefinite	x
United States	x	x		20 years	

[a] Some regional tax incentives provide 10 year carry forward; [b] For "New tax Relief"; [c] SIFIDE II; [d] RDA tax incentive: For self-employed carry-back possible for 3 years, companies 1 year; [e] Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details

5.3 Organization

Every policy needs to be set against the actual budget costs and administrative capacities. A key aspect from a budgetary perspective is the preferential rate that will be offered; we have summarized this under "generosity". Administrative capacities determine the operational efficiency of the instrument, which also affects the compliance costs of firms. This is presented under "administration".

5.3.1 Generosity

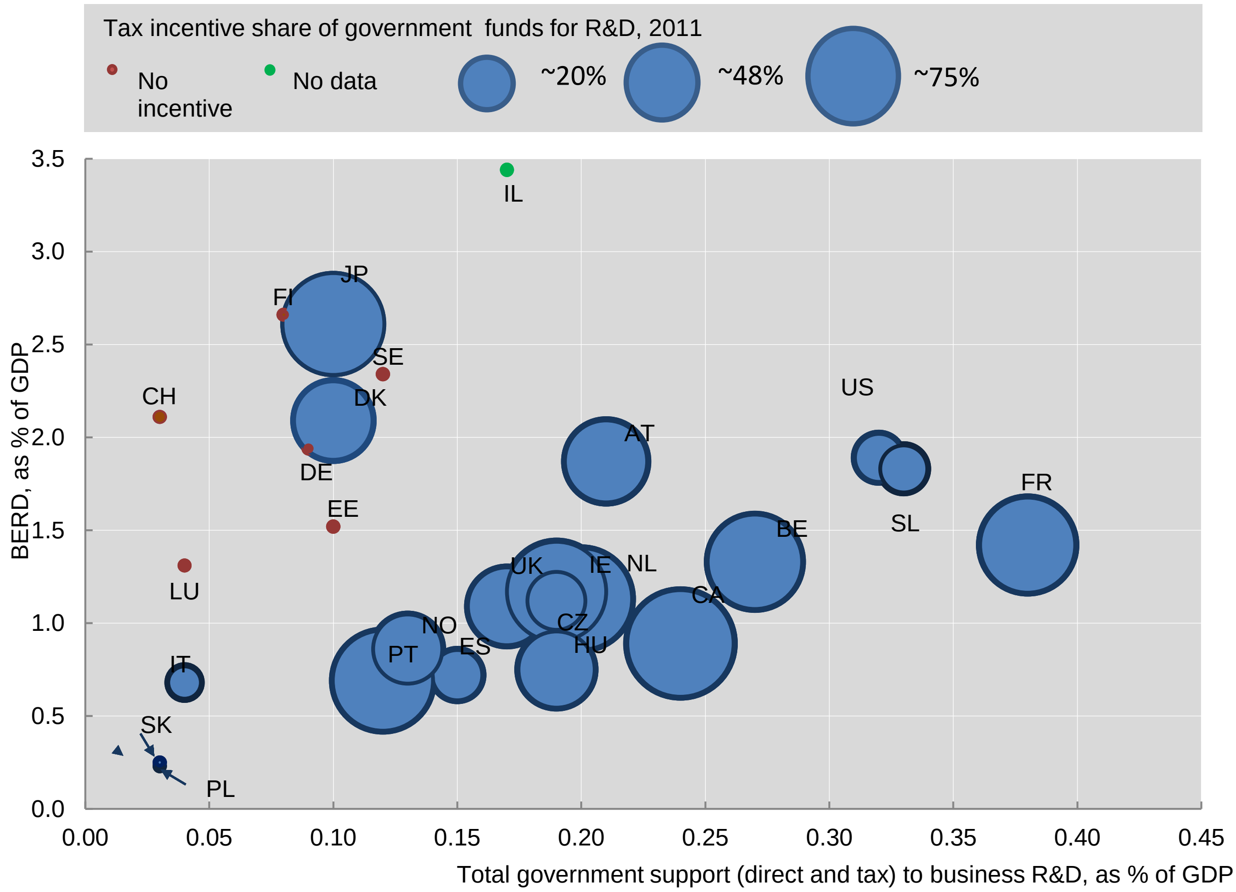
Government expenditure on private R&D varies substantially across countries. Figure 5.5 shows the relation between business expenditure on R&D (BERD) and government support for BERD. In addition, the size of the bubbles reflects the share of the governments R&D support budget that is spent on R&D tax incentives. It shows that in France, The Netherlands, Ireland, Belgium, Portugal, Japan and, especially, Canada R&D tax incentives play a major role in government funding for R&D, varying between 68.4 percent (in France) to 85.5 percent (in Canada).

The figure shows that more support to R&D (as a percentage of GDP) is somewhat related with higher levels of BERD (as a percentage of GDP).

There are notable exceptions, however. Finland, Japan, Sweden, Denmark, Switzerland and Germany that have high BERD but relatively low total government support to business R&D (as percentage of GDP) and no R&D tax incentives in 2011. Across all countries in the sample there appears to be no relation between the tax incentive share of total government funds to R&D and BERD (correlation coefficient of 0.04). While the figure is only illustrative and the data experimental[33], these trends indicate that while tax incentives may be beneficial to support private R&D, it appears not to be a necessary condition in several countries.

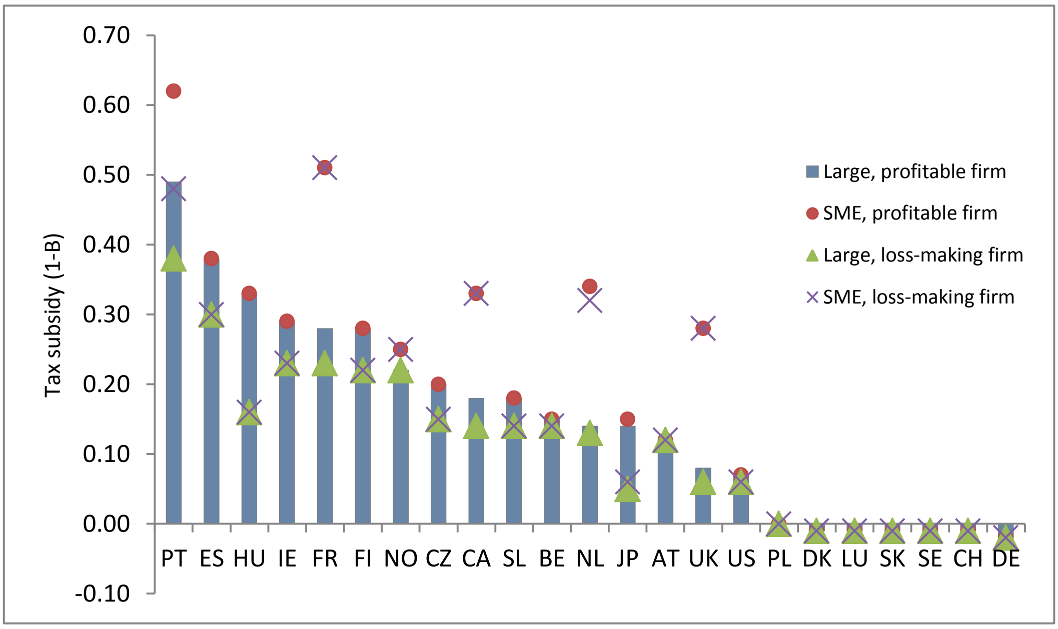
[33]Data taken from OECD, 2014, Summary description of R&D tax incentive schemes for OECD countries and selected economies, 2013. www.oecd.org/sti/rd-tax-stats.htm, accessed on 18.06.2014.

Figure 5.5 Business R&D intensity and government support to R&D, 2011



Source: OECD, 2014, www.oecd.org/sti/rd-tax-stats.htm, accessed on 18.06.2014

Figure 5.6 Tax subsidy rates on R&D expenditure for OECD countries, 2013

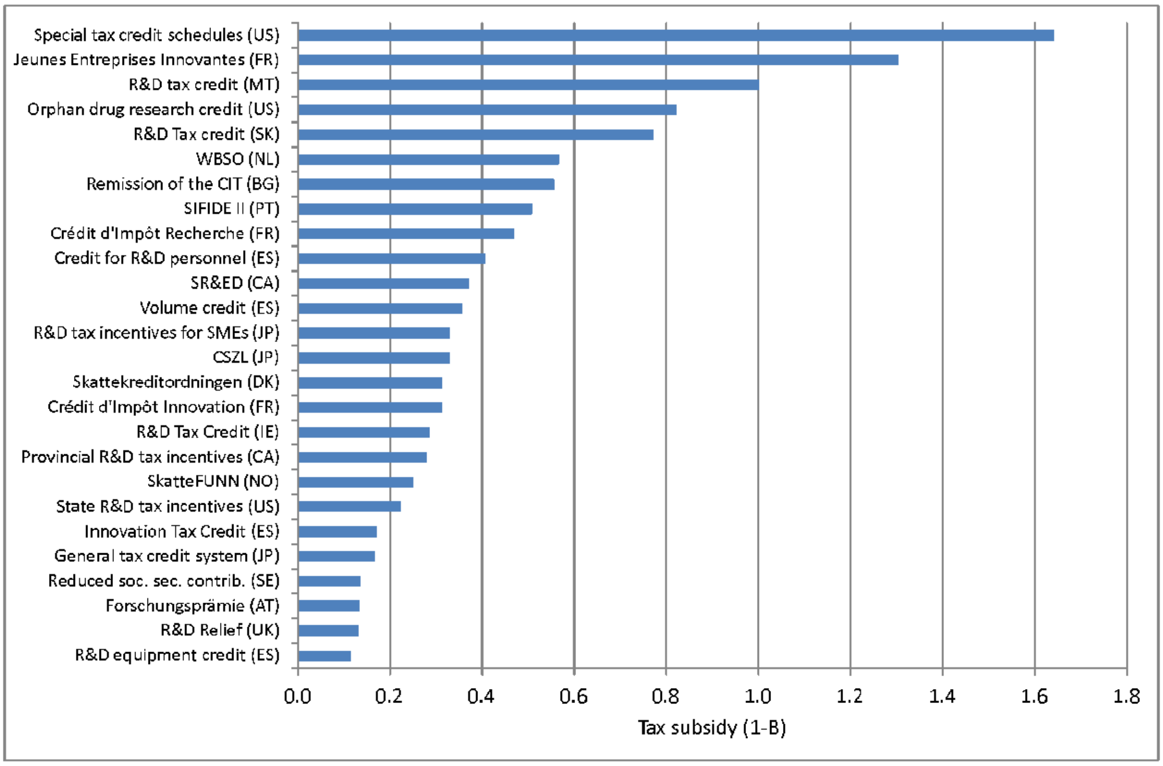


Source: OECD, www.oecd.org/sti/rd-tax-stats.htm, accessed on 18.06.2014
The generosity of a scheme depends, among other things, on the corporate tax rate in a country. One way to compare the generosity of tax incentives between countries, while taking differences in corporate tax rates into account, is to calculate the B-index. Figure 5.6 shows tax subsidy rates across OECD countries, measured as one minus the B-Index. The B-index shows how much before-tax income is needed for a firm to break even on one euro of R&D costs (Warda, 2001). The tax subsidy rates are distinguished by firm size and profitability status. However, note that B-index does not take into account ceilings- it assumes a 'representative firm' whose expenditure does not exceed the maximum allowed level of benefit.

The most generous R&D tax incentives appear to be in Portugal, France and Spain. As noted in the section on targeting, countries differentiate the level of generosity across firm types. This is reflected in the table, where Portugal, France, the Netherlands, Canada, Great Britain, Korea, Norway, Australia and Japan offer a more generous treatment for SMEs than for large enterprises. SMEs that do not have profits enjoy the same level of tax generosity as profitable SMEs in France, Canada, Great Britain, and Norway.

At the level of instruments, a different picture arises. We have computed the tax subsidy rate for volume-based R&D tax credits at the most detailed level.[34] A first observation is that the most generous tax credits, the American special tax credit schedules, the French scheme for Young Innovative Companies (J.E.I.), and the Maltese tax credit are very generous as they imply a tax subsidy exceeding one hundred percent.

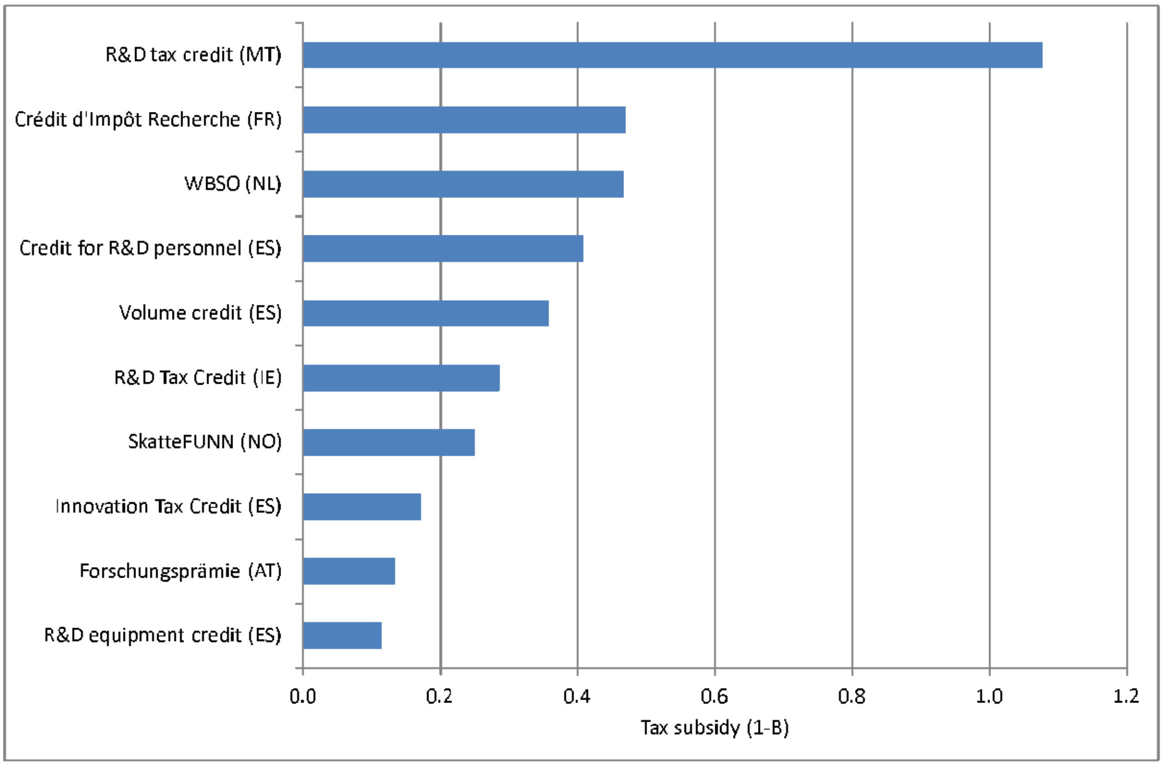
Figure 5.7 Tax subsidy rates volume-based R&D tax credits



[34] We calculated the tax subsidy as 1 – B-index = 1 - (1–u-c)/(1-u) = c/(1-u), where c is the rate of the tax credit and u is the corporate income tax rate, see Warda (2001) p. 205.

Figure 5.8 compares the generosity of volume-based R&D tax credits that are not targeted to specific types of firms. These untargeted schemes are less generous on average. Except for the Maltese scheme, the tax subsidy now is below fifty percent. The opposite is true for R&D tax credits targeted at SMEs and startups (Figure 5.9). In this category, four instruments have a tax subsidy rate that exceeds sixty percent.

Figure 5.8 Tax subsidy rates for untargeted volume-based R&D tax credits



Patent boxes offer reductions of the corporate income tax rate that firms have to pay on their IP income. Figure 5.10 summarizes the effective corporate tax rate that firms pay on profits generated from intangible assets eligible for patent boxes. In Malta and France income from intellectual property is completely exempted from the corporate income tax in the first year. For France the effective rate increases to 15 percent in subsequent years, offering the highest rate amongst the patent boxes. Spain follows with 12 percent and Hungary with 9.5 percent.

Tax subsidy rates and effective tax rates only offer partial information on the generosity it ignores the scope of the instrument. As a further indication of how schemes differ in terms of generosity, Table 5.6 shows government expenditure per R&D tax incentive for a subset of instruments. The largest scheme in absolute value is the French Crédit Impôt Recherche, with 4.8 bln euro, followed by the Canadian SR&ED, 2.6 bln euro. The instrument ranked last is the Maltese R&D tax credit.

Figure 5.9 Tax subsidy rates for R&D tax credits targeted at SMEs and start-ups

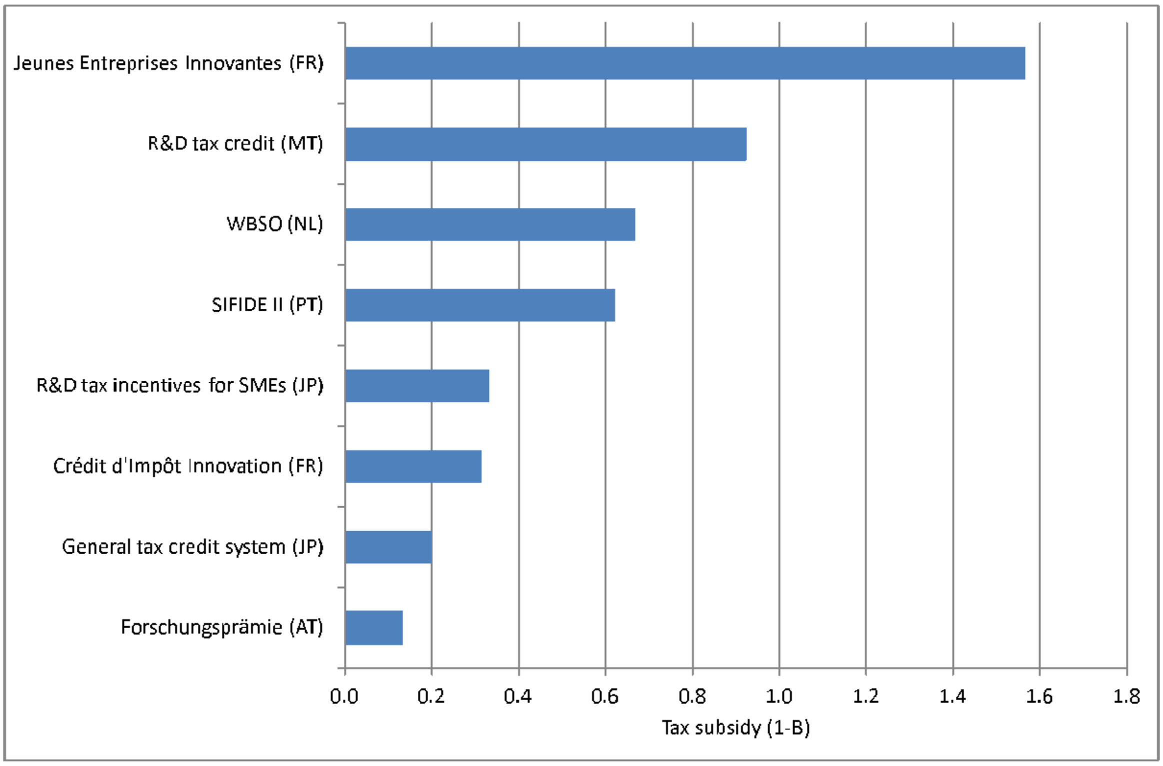
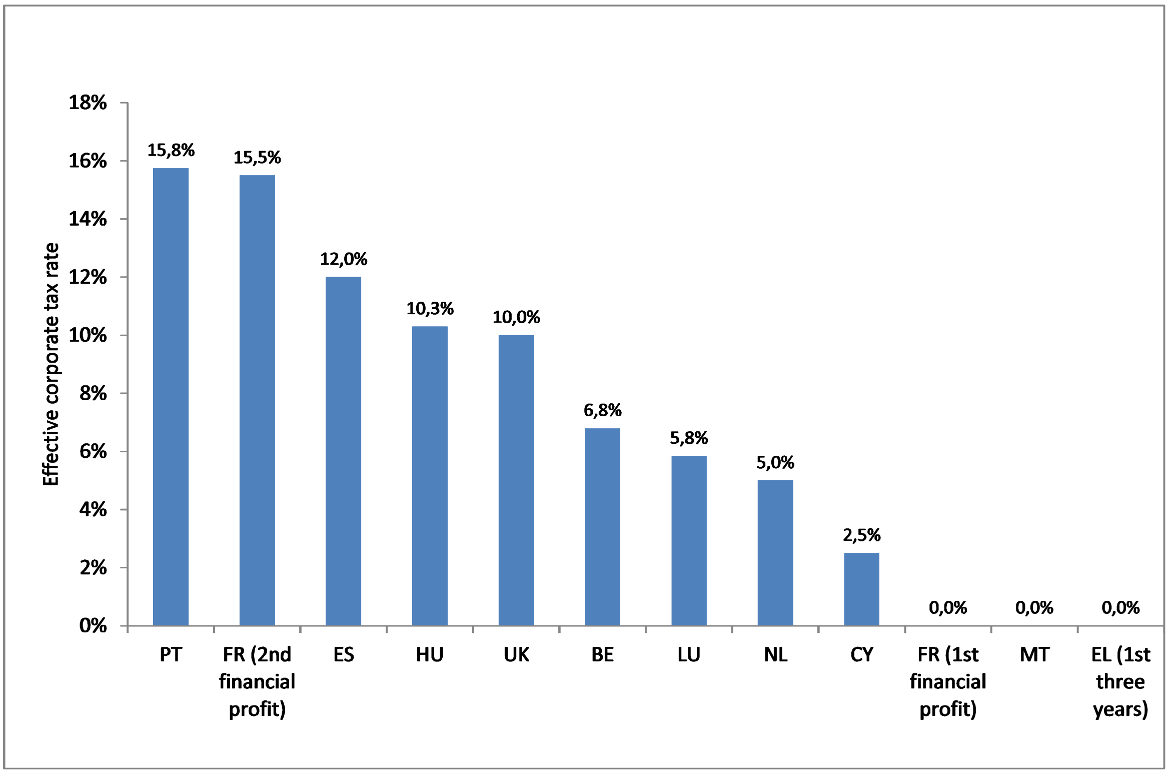


Figure 5.10 Effective corporate tax rates for income derived from patents



Source: own calculations (see Annex with country fiches for detailed sources)

Table 5.6 Government expenditure on R&D tax incentives (mln EUR)

Instrument name	Budget (EUR mln)	Year	Source
Crédit d'Impôt Recherche (FR)	5800	2014	Loi Finances pour 2014
SR&ED (CA)	2591	2012	Budget 2013
Credit for Incr. Res. Act. (US)	997	2011	US Office of Management and Budget's
WBSO (NL)	765	2014	Netherlands Enterprise Agency
The Patent Box (UK)	747	2013-14	Budget 2013
Section 174 tax deduction (US)	663	2011	US Office of Management and Budget's
Innovatiebox (NL)	625	2012	Ministry of Finance
Forschungsprämie (AT)	550	2013	Austrian Research and Technology Report 2013
New Tax Relief (PL)	440	2012	Ministry of Finance
Payroll tax deduction for R&D (BE)	339	2011	Belspo
RDA (NL)	302	2014	Netherlands Enterprise Agency
Crédit d'Impôt Innovation (FR)	300	2014	Loi Finances pour 2014
SkatteFUNN (NO)	282	2013	SkatteFunn Arsrapport 2013
R&D Relief (UK)	280	2014-15	Budget policy costings 2013
R&D Tax Credit (IE)	261	2011	Review of Ireland's R&D tax credit 2013
Deduction for R&D wages (FI)	155		Finnish Tax Administration (VERO SKATT)
Patent Income Deduction (BE)	114	2011	Research and Documentation Department & High Council of Finance
Patent box (FR)	112	2014	Loi Finances pour 2014
Jeunes Entreprises Innovantes (FR)	112	2014	Loi Finances pour 2014
Skattekreditordningen (DK)	40.3	2013	The Danish Ministry of Taxation (Skatteministeriet)
Reduced soc. sec. contrib. (SE)	46	2014	Skatteverket
R&D tax credit (MT)	36	2010	Erawatch 2012: Malta

5.3.2 Administration

An effective application procedure is crucial for the pool of beneficiary firms. Table 5.7 shows that most countries offer the possibility of online application and a 'one-stop' application process for at least one of the R&D tax incentives in their country. Those two aspects of the administrative procedure enhance the efficiency of the schemes since they reduce both the administrative burden for governments and compliance costs for firms.

R&D tax incentives require substantial government expenditure. Therefore, assessing whether the scheme has reached its intended policy goals is essential. Only six countries have planned evaluations for at least one of their R&D tax incentives. Yet, regardless of whether there was a legal obligation, schemes were evaluated in 14 countries. Part of the evaluations carried was academic, others- organized by the responsible ministries.

Table 5.7 Administrative features among countries

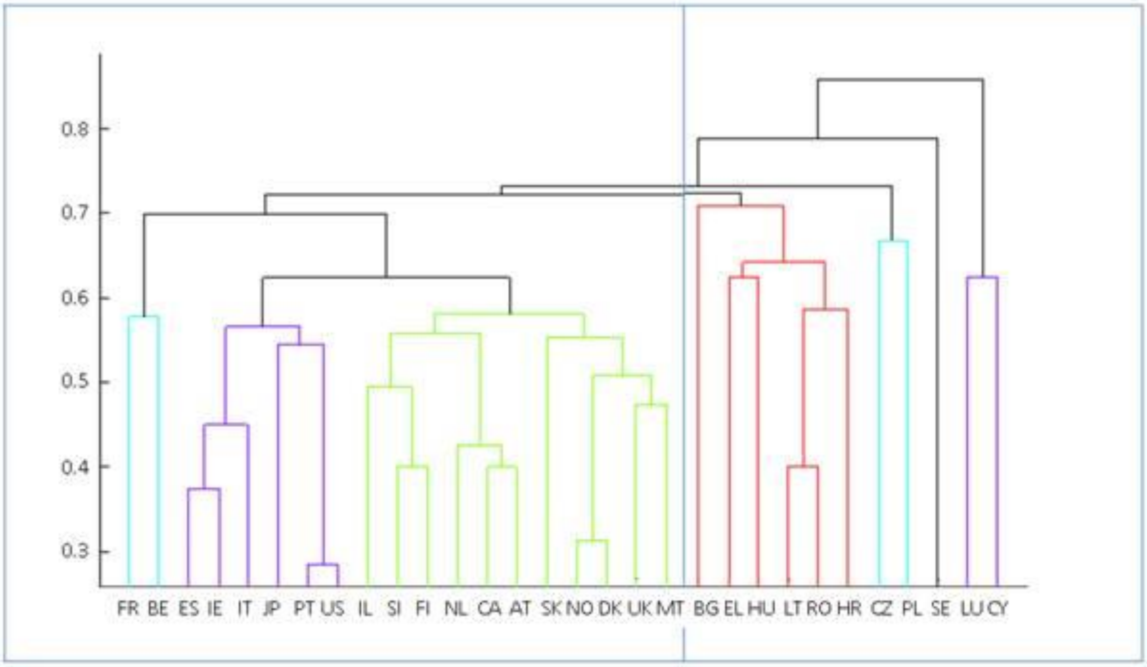
Country[a]	E-application	One-stop	Evaluation planned	Evaluation performed
Austria	x	x		x
Belgium	x	x	x	x
Bulgaria				
Canada	x	x		x
Croatia				x
Cyprus				
Czech Republic	x	x		
Denmark	x	x	x	
Finland	x	x	x	
France	x		x	x
Greece	x			
Hungary				
Ireland	x	x		x
Israel	x	x		
Italy	x	x		x
Japan		x		x
Latvia	x	x		
Lithuania				
Luxembourg				
Malta		x		
Netherlands	x	x	x	x
Norway	x	x	x	x
Poland		x		
Portugal	x	x		x
Romania				
Slovak Republic	x	x		
Slovenia	x	x		
Spain	x	x		x
Sweden	x	x		
United Kingdom	x	x		x
United States	x	x		x

[a]Estonia and Germany were included in the analysis but they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

5.4 Clustering analysis

As outlined above, R&D tax incentives vary considerably in terms of their scope, targeting and organization features. This is also the case for different instruments used in the same country. Nevertheless, the "instrument mix" in one country can be similar to the instrument mix in another. To identify the level of clustering among the countries' instruments, the different identified characteristics across 30 countries[35] were summarized in a country- design features matrix[36] (see Figure 5.8).

Figure 5.11 Dendrogram of country similarity for R&D tax incentives



Source: own Hierarchical Clustering Model, on basis of data collected for this report

The clusters shown by different colours in the dendrogram illustrate relationships between the identified features of the R&D tax incentive schemes offered in different countries. The lower the bar (the closer to zero), the more similar are the countries grouped together. On this basis, six groupings of countries can be identified (indicated by different colours). From the left- France and Belgium; Spain, Ireland, Italy, Japan, Portugal and the United States; Israel, Slovenia, Finland, The Netherlands, Canada, Austria, Slovak Republic, Norway, Denmark, United Kingdom and Malta. Those three groups are also more similar with each other than with the group of Bulgaria, Greece, Hungary, Lithuania, Romania, Croatia and Czech Republic, Poland; Sweden; and Luxembourg, Cyprus.

Within those groups, Portugal and the United States have the most similar tax incentive schemes[37], followed by the pair Norway-Denmark, and at a somewhat lesser

[35]The method is restricted to 30 units. Latvia was not included in this analysis, whose R&D tax incentive is very similar to Lithuania's. Estonia and Germany are also not included as they do not offer any type of R&D tax incentives (see annex with country fiches for more details)

[36] Based on the *hierarchical clustering* method. Described in more detail in Appendix

[37] The strong commonality between the R&D tax incentives schemes of Portugal and United States is grounded in both featuring: the incentive base is R&D costs and expenditures (direct and/or indirect); tax base is corporate income; type of tax

degree, Spain-Ireland, Slovenia-Finland, Canada-Austria (which are also close to Netherlands), and Lithuania-Romania.

Sweden appears to have the most ‘unique’ R&D tax incentive system, as it does not match with any other one country.

incentive being tax credits; that is both volume and incremental; that target according to firm size and firm age; that has ceilings on the amount claimed; that may only be carried forward; and that offer firms both electronic application in a one-stop-shop setting.

6 Benchmarking R&D tax incentive designs

What are good designs for R&D tax incentives and which properties are to be avoided? The literature survey provided in earlier chapters yields general conclusions on the effectiveness of R&D tax incentives, but does not offer direct guidance to which incentive schemes are recommendable and which not. In order to identify good practices among R&D tax incentive schemes, we have rated them by comparing their observed characteristics with a set of principles for good practice. Altogether over eighty such instruments are offered in 31 countries.[38]

The benchmarking procedure involves three steps. First, a set of twenty principles for good practice was established using both empirical and theoretical insights. These principles fall into the categories scope, targeting and organization. For most good practices also a corresponding non-recommendable practice was identified. Next, all R&D tax incentives were compared with these principles. With the third step, the scores on individual principles were used to rate the different R&D tax incentive schemes.

The rating of an instrument gives an indication of its potential to foster more R&D and innovation in a country, but does not reflect direct evidence that might be available for this instrument. Direct evidence on economic outcomes of these instruments – which may include, the take-up of tax instruments, the costs of administration and compliance, and overall evaluation – is outside the scope of this particular exercise as for many countries no direct evidence is available. Also, evaluations are performed differently across countries, which make it difficult to compare results. Benchmarking requires that the availability of information across countries is as equal as possible.

Besides the ranking of R&D tax incentives schemes, we also provide an overview of whether data is available that allows for their evaluation. Here, we benchmark countries rather than instruments as data availability is difficult to assess at the instrument level.

6.1 Principles of good practice

Identified design and administrative elements of R&D tax incentives are assessed according to theoretical considerations and findings of the econometric studies in chapter two.[39] As a general principle, larger weight is given to empirical evidence. The different features have been assessed for three categories of features (see also the overview of incentives in Chapter 5):

1. scope of the policy, including the type of R&D tax incentive and costs covered
2. targeting of specific groups of firms, according to their size, age, region, etc.
3. organization, including administrative practices and evaluation

We here present the discussion on the different elements of each category and provide ‘best’ and ‘not recommended’ practices for each element. Most of these principles of good practice will be used in the benchmarking analysis. Table 6.1 summarizes the principles of good practice.

[38] The number of instruments depends on the definition of an instrument: what is known as a single instrument in one country might be known as two separate instruments in another country. Our approach is detailed in Section 6.2.

[39] Principles for best practices were suggested earlier by the European Commission (2007). Most of the principles proposed in this report are deducted independently from the literature survey, but they are largely consistent with the principles suggested earlier.

Table 6.1. Summary of principles of good practice

Category	Practice	Best practice	Not recommended
Scope	Input related vs. output related R&D tax incentive	Input related	Output related
	Tax credits vs. enhanced allowances	Tax credits	
	Volume-based vs. incremental	Volume-based	Incremental
	Novelty requirement	New to the country (world)	Explicit incentive for imitation
	Expenditure covered	R&D wages	IP costs
Targeting	Region	Common rate for the country	Very specific design elements in different regions
	Legal form	Common rate for all legal entities	Exclusion of firms with foreign owner
	Firm size	No targeting	Targeting at large firms
	Brackets and ceilings	No brackets	Lower rate for small amounts
	Firm age	Young firms	Incumbents
	Field of activity/type of technology	No targeting	Targeting
	Minimum	No minimum	High threshold
	Negative tax	Yes, for young firms	No negative tax
	Carry-over provisions	Yes, for young firms	No carry-over provision
	Collaboration[a]	With public research institutes	Upstream R&D cooperation between large competitors
	Generosity[b]	Ambiguous	Over-subsidizing
Organization	Decision time/refund	Minimum possible	Longer than 1 year
	Electronic application	Yes	No
	One-stop application	Yes	No
	Public consultation	Yes	No
	Evaluation	Yes, planned	No
	Synergy[a]	Complimentary	Overlapping
	Stability[a]	Fixed design and rates for at least 5 years	Large and unexpected changes in the budget

[a]Best practise principle is described, but not included in benchmarking due to lack of data.

[b]Evidence on optimal generosity is insufficient for identification of best practices; descriptive information on the generosity of schemes is provided in Section **5.3.1**.

6.1.1 Scope

Input related versus output related

Best practice: Input related

Not recommendable: Output related

Input-related tax incentives (tax credits, enhanced allowances, accelerated depreciation) apply to expenditure on R&D, while output-related incentives (patent boxes, tax benefits for IP-related expenditure) apply to the income or assets generated from R&D. The evidence discussed in Chapter 2 shows that input-related R&D tax incentives are inducing more R&D expenditure. Studies of output-related incentives show that these incentives are related with higher number of registered patents (Chapter 3). Yet, for output-related incentives there are indications that this was due to reallocation of intellectual property, rather than due to creation of new innovative products (Griffith *et al.*, 2014; Karkinsky and Riedel, 2012; Ernst and Spengel, 2011; Bohm *et al.*, 2012). In addition, these incentives lead to a substantial drop in the government revenue (Griffith et al., 2014). The empirical evidence suggests that input-related incentives are more likely to be effective than output-related incentives.

Input-related incentives are also to be preferred from a theoretical perspective for two reasons. First, inventions protected by patents are much less likely to generate externalities, such that the case for fiscal support of income derived from patents is weak. Second, as not all innovation is patented supporting products protected by IPR can result promoting sectors or types of firms that generate smaller spillovers. This may increase market failure rather than reduce it.

Tax credits versus enhanced allowances

Best practice: Tax credits

Neutral: Enhanced allowances

The vast majority of empirical studies have analyzed R&D tax credits. Therefore, it is difficult to draw detailed conclusions on how the impact on firm R&D behaviour varies with the type of tax incentive. From an economic point of view there is little difference between corporate income tax credits and enhanced allowances. From an administrative point of view, Lester and Warda (2014) argue that tax credits are preferred over enhanced allowances because the former vary with the corporate tax rate. Whenever there is a change in the corporate income tax rate, the rate of enhanced allowance should follow to adjust for this change. This is not the case with tax credits.

Volume-based versus incremental tax scheme

Best practice: Volume based incentives

Not recommendable: Incremental incentives

It is often argued that incremental schemes are more efficient than volume-based instruments. This is because the benefit is applied only to the incremental part of the R&D expenditure, rather than the total as with volume-based schemes. Presence of dead-weight losses were found in studies analyzing volume-based R&D tax incentive schemes (Lokshin and Mohnen, 2012 and 2008 for Netherlands; Baghana and Mohnen, 2009 for Canada; Lee, 2011 for Taiwan; Bloom *et al.*, 2002 for OECD countries.) The presence of dead-weight losses for volume-based schemes does not imply that incremental schemes are more efficient. Lester and Warda (2014) show that even at low levels of firm growth, the cost-effectiveness of the incremental scheme will be the same as for the volume based.

A theoretical argument against incremental schemes is that they distort R&D investment planning (see Section 2.1.3): if firms plan their R&D investment expenditure several years ahead, then an incremental scheme will impose a restriction on the optimal time path whereas a volume-based will not. Due to this distortion, incremental schemes could result a higher dead-weight loss when firms are forward-looking.

A practical argument against incremental schemes is that they are more complicated to administer than volume-based schemes: there can be problems with defining the baseline and there are choices to be made on whether to move the baseline or not. This results in higher compliance costs. All this makes volume-based schemes a better practice.

Novelty requirement of the intended outcome

Best practice: New to the world; new to the country

Not recommendable: Explicit incentive for imitation

The novelty requirement 'new to the world' supports R&D with potentially largest social returns. It provides beneficial treatment to those firms investing in more radical innovation, rather than promote imitation (see Section 5.1.5). One drawback of strict novelty requirements is that it involves high administrative and compliance costs. A second argument can be that for countries that are far away from the technological frontier, it might have some merit to stimulate adoption of foreign technologies. The strength of this argument is limited as such a policy might also deter foreign investment in R&D activity.

A novelty requirement 'new to the country' can be considered second best practice. It does not support imitation between firms located in the same country and is easier to implement.

Offering fiscal benefits to R&D that is targeted at imitation is not an advisable practice. Particularly in case of weak IPR, such design element promotes the negative externalities on innovation. It may work against investment in radical innovation and increase the gap between socially desirable and observed levels of innovation.

Expenditure covered

Best practice: R&D wages

Neutral: Expenditure on R&D inputs

Not recommendable: IPR costs

From the viewpoint of economic theory, tax incentives should apply to those types of expenditures that have strong externalities. Of all types of expenditure related to R&D, wages paid to researchers are likely to have the strongest externalities as (former-) employees are an important channel through which knowledge diffuses unintentionally to other firms. A practical advantage of tax incentives for R&D wages is that they have low administration and compliance costs. In particular, it may be more straightforward to distinguish R&D and non-R&D labor than R&D and non-R&D investment. For these reasons, it can be considered good practise to have tax incentives for R&D wages.

As other types of expenditure on R&D, like capital expenditure, might also become less attractive due to knowledge spillovers caused by researchers, tax incentives for these types of expenditure can also be justified - although capital-intensive R&D activities might be difficult to replicate because of entry barriers.

Expenditure on intellectual property rights reduces externalities as IPRs prevent the unintended diffusion of technology. Although IPRs can stimulate innovation, it is not clear why tax incentives are an efficient way of reducing a firm's barriers to obtaining

IPRs. In particular, tax incentives for IPR acquisition are biased against technologies that are difficult to patent. We consider tax incentives for expenditure on R&D in general as neutral. See also Chapter 3.

6.1.2 Targeting

Region

Best practice: No targeting on regions

Not recommendable: Very specific design elements in different regions

In order to spur innovative activity, a more preferential rate could be applied in less advantaged regions. These types of policy are not likely to be efficient for two main reasons. First, the impact of R&D tax incentives in a targeted region will be interrelated with the broader innovation system in that region. If framework conditions in that region are not satisfactory, simply offering a higher rate of support is unlikely to have an effect on innovation. Second, offering different rates of benefits for different regions creates an uneven playing field, which might trigger firms to move their R&D activities to targeted regions. This could work against economies of scale offered by R&D intensive regions and will lead to less innovation at the national level. An uneven playing field also introduces moral hazard since firms can administratively base some of their units in the preferential tax zone purely for tax reasons. This complicates the system and results in additional compliance and administrative costs.

Legal form

Best practice: Common rate for all legal entities

Not recommendable: Exclusion of firms with foreign ownership

Innovation can arise in various forms and from different actors in the economy. Targeting to particular legal forms will create uneven playing field that can hamper the dynamics of economic activity and overall innovative performance. Excluding firms with foreign owners can be particularly to counterproductive as it discourages R&D-related FDI inflows and knowledge spillovers from foreign affiliates. Access to foreign knowledge is especially important for countries that are catching up in their innovation performance.

Firm size

Best practice: No targeting on firm size

Neutral: Targeting of SMEs

Not recommendable: Targeting on large multinational firms

There is no clear empirical reason why a scheme's generosity should vary with firm size. The evidence on whether small firms respond more strongly to R&D tax incentives than large firms is mixed (see Section 2.1.6). In addition, knowledge spillovers are not stronger for small firms as the gap between social and private returns to R&D is more profound for large firms (Bloom et al. 2013).

Not recommendable practice is to provide stronger incentives for large multinational firms. Those companies have wide access to finance and cross-border tax planning possibilities that put them at an advantageous position with respect to domestic firms. Additional support to multinationals could result in large dead-weight losses and a distorted competition environment. Targeting of SMEs is treated as a neutral practice (the targeting young firms is discussed below).

Brackets and ceilings

Best practice: No brackets

Neutral: Ceilings

Not recommendable: Lower rate for small amounts

Brackets and ceilings indirectly target tax incentives based on firm size as small firms tend to have smaller R&D budgets than large companies. As has been argued above, there is no clear empirical reason to vary the generosity of a scheme with firm size. Besides clear evidence on the benefits of brackets and ceilings, they have the disadvantage of distorting the optimal R&D investment planning of firms, as they have an incentive to distribute the expense in a way to obtain the maximum tax benefit, spreading R&D budgets over time and over subcontractors. Ceilings are treated as neutral as they have the practical advantage of maintaining control over the budget allocated to the tax incentive.

Firm age

Best practice: Targeting on young firms

Neutral: No targeting on firm age

Not recommendable: Targeting on incumbents

Highest level of uncertainty is in the very early stages of innovation processes. In particular, potential investors have less information about innovation projects than entrepreneurs have. This uncertainty restricts the access of innovative firms to external funding. Obtaining finance is especially difficult for start-ups as they lack collateral and a track of record that can provide more certainty to financiers. These entry barriers result in overall lower competition and possibly less pressure on incumbents to innovate. Young firms could be provided with more favourable rates to lower those barriers and to stimulate competition.

Not recommended is preferential treatment of large incumbent firms as this discourages innovation by new entrants and reduces the competitive pressure on incumbent firms to innovate.

Field of activity/type of technology

Best practice: No targeting

Not recommendable: Targeting

A reason to target specific sectors would be that knowledge spillovers are stronger in some sectors than in others. The evidence on heterogeneity in knowledge spillovers, across sectors have is not clear, such that it is not clear which sectors should be targeted. Targeting specific sectors or technologies has the potential drawback that it could discourage innovations that arise from a combination of different technologies. Tying fiscal support to specific fields can restrict recombination and can result in less innovation.

Minimum

Best practice: No minimum

Not recommendable: A very high threshold, equivalent to targeting at large firms

Setting a minimum expenditure can have the practical advantage of avoiding administration costs that are high compared to the fiscal incentive, but they are also biased against young firms as they tend to have lower R&D budgets. Any requirement to invest a specific amount in R&D before a tax benefit can be received puts firms at a disadvantageous position that are potentially important for the innovativeness of an economy in the long run. A high minimum requirement works in favour of large incumbents and can distort competition.

Negative tax

Best practice: Yes, for young firms

Not recommendable: No negative tax

Innovative firms are not likely to make profits in the first years of operation. A 'negative tax' option provides firms with cash refunds in case they do not have profits. In the absence of a 'negative tax', young firms cannot benefit from the tax incentive simply because they have no taxable income. This could have adverse effects on competition and might result in overall lower innovative activity.

Carry-over provision

Best practice: Yes

Not recommendable: No carry over provision

There can be a considerable time lag between expenditure on R&D and the profits generated by innovation. The option to carry forward all or part of tax benefits based on R&D expenditure to other years is likely to be important for the effectiveness of R&D tax incentives: it enables firms to take full advantage of corporate income tax credits and provides firms with more flexibility in their investment decisions. This option is especially important for young firms when a cash refunds are not available as they have limited possibility to pre-finance R&D tax benefits they will receive tin the future.

Collaboration

Best practice: Yes, for collaboration with public research institutes

Not recommendable: Upstream R&D cooperation between large competitors

Cooperation between firms and public research institutes, like universities, can facilitate innovation based on scientific research. Studies show that more connected firms are also more innovative (see Nooteboom and Stam (2008) for a review). As public research institutes publish at least part of their results, it can be argued that the results of cooperation between firms and public research institutes have stronger knowledge spillovers. A study by Dumont (2013) on Belgium's R&D tax credits showed that a scheme focusing on research cooperation had a larger positive impact than other schemes.

While R&D cooperation amongst firms can produce innovations that are less likely to have been generated by a single firm, these activities should not receive additional support because 1) there are few reasons to expect that this type of cooperation will generate stronger knowledge spillovers than other private R&D activities and 2) also cooperation on R&D can reduce the competitive pressure on incumbents. Duso *et al.* (2014) showed that upstream R&D cooperation between large competitors create distortions in the product market that results in the loss of consumer welfare.

6.1.3 Organization

Stability

Best practice: Fixed design and rates for at least 5 years

Not recommendable: Large and announced changes in the budget

Frequent and substantial policy changes are likely to strongly reduce the effectiveness of policies - regardless of their design (Westmore, 2013). Predictability of the policy is crucial for firms to integrate the tax benefit in their R&D investment plans, which can span many years. If a policy instrument is changed frequently and on irregular basis, a tax incentive will not be fully taken into account when firms make their investment decisions. This decreases the effectiveness and efficiency of the policy.

Generosity

Best practice: Uncertain

Not recommendable: Over-subsidizing

The optimal generosity of a scheme is difficult to determine. On the one hand, generous fiscal R&D support is correlated with a higher share of incumbent firms and a narrower growth distribution in R&D-intense sectors (Bravo-Biosca *et al.*, 2013). On the hand, small incentives are unlikely to have an impact on the behaviour of firms. The impact of generosity is likely to be nonlinear and related to the specific design of the policy, target groups and the framework conditions in place. Evidence on optimal generosity is lacking, making it uncertain what the best practice is.

Decision/refund time

Best practice: Minimum decision time possible

Not recommendable: More than 1 year after investment

For young, liquidity constrained firms access to external finance is crucial for growth. Especially for these firms, the decision time and the reimbursement of the benefit should be as short as possible. If the decision on the refund comes long after the investment has been made, young firms may not respond to the policy. This will distort competition as more mature firms have less binding liquidity constraints.

Electronic application and one-stop agency

Best practice: Yes

Not recommendable: No

Electronic application and a one-stop agency where firms can settle all relevant questions substantially reduce the administrative burden for governments as well compliance costs for firms. In particular startups might be discouraged to apply for a tax incentive when they face uncertainty about compliance costs. Online application improves the take-up rates and the efficiency of administrative process.

Public consultation

Best practice: Yes

Not recommendable: No

Routine public consultations can help government to acquire the information necessary for an effective design and organization of tax incentives. Public consultations also improve the transparency of policy decisions and give all interested parties to give their views before decisions are made. When using public consultations, policymakers should bear in mind that not all relevant parties will participate - think about next year’s startup for example.

Evaluation

Best practice: Yes, preferably planned and regular

Not recommendable: No

Probably no invention will work as intended when tried the first time - and the same holds for new government policies. Without rigorous and unbiased evaluations, it will not be likely that policies will work as intended. For a policy to become and remain effective, it is necessary to organize evaluations on regular basis. If the organization of evaluations is embedded in the legal system, this will also motivate governments to organize the availability of high-quality data.

Synergy

Best practice: Complimentary policy instruments

Not recommendable: Overlap between different policy instruments

Combining R&D tax incentives with direct support can help to address funding to projects with higher social returns. Policy instruments should not be overlapping as that would unnecessarily increase the bureaucratic apparatus and provides firms with a 'double' subsidy for one and the same activity. This reduces the overall policy efficiency.

6.2 Methodology

In order to be able to benchmark the tax incentives, we systematically collected information on scheme characteristics. The unit of observation for data collection is formed by unique combinations of the country, the name of the instrument, the type of tax incentive and the target group. For each unit of observation information was collected on the nineteen variables discussed above. This procedure enables a quantitative assessment of each individual instrument, which is summarized into a combined rating score that takes the variables evaluated into account.

The nineteen variables used for benchmarking address the scope of the instruments (five variables), features related to the targeting of instruments (nine variables), and organization characteristics (five variables). Three other variables, namely collaboration between companies and other organizations (an aspect of targeting), stability of tax instruments offered over time and synergy between policy instruments in individual countries (both concerning organization) were not readily amenable to the benchmarking procedure described below because of a lack of data. Another variable, generosity was not included as there is insufficient evidence on optimal levels of generosity for identification of best practices. Descriptive information on the generosity of schemes is provided in Section 5.3.1.

For each variable a unit of observation (sub scheme) was classified as either "Best practice", "Non-recommended", or "Neutral". This basic information was in turn transformed into a 3-point scale: "1" for best practice; "-1" for non-recommended practice; and "0" for "neutral". From these scores, means were taken for the categories "Scope", "Targeting", and "Organization". The overall score per unit of observation was subsequently calculated as the mean over the three categories.

Two adjustments were made with this last step: First, scores on scope are systematically larger than those on targeting and organization. We corrected for differences in the mean score between these categories by dividing each category score by the mean for that category. In addition, we rescaled the overall score by multiplying it by the overall mean score. The second adjustment is that the score on "Organization" gets a double weight. The reason for doing this is to give equal weights to theoretical and practical aspects of the incentive design: both the categories "Scope" and "Targeting" are of a theoretical nature, while "Organization" is concerned the practical aspect.[40]

[40] The overall score is computed as follows:

$$t_i = \frac{1}{4}\left(\frac{s_i}{\bar{s}} + \frac{t_i}{\bar{t}} + \frac{2o_i}{\bar{o}}\right)\left(\frac{\bar{s} + \bar{t} + 2\bar{o}}{4}\right)$$

Next, all sub schemes were aggregated by taking means across target groups for each variable. The resulting unit of observation is formed by unique combinations of the country, the name of the instrument, and the type of tax incentive.

This coding gives rise to the overall rating of instruments by the 3r score ("3-point rating").[41] If the number of best practice ratings outweighs (is outweighed by) the number of non-recommended ratings, then the 3r score will be positive (negative) and lie between zero and one (minus one).

Not all information on every variable is available for each instrument in the database. Missing values were coded as zeros, which has the effect of 'discounting' the results.[42] Thus the more reliable the estimated score – i.e. the higher the number of valid benchmarks on which it is based – the less is the discount factor.[43] This approach was undertaken as the vast majority of the missing values were a result of a lack of available information. This may indicate compliance costs that firms face when applying to an R&D tax incentive- if information is not clear and easily accessible, compliance costs for firms will be high. High compliance costs will, in turn, lead to lower policy effectiveness, as described previously.

The overall result of the benchmarking of R&D tax incentive instruments in the countries analysed is a summary value, the '*3r* score'. For most of the schemes, 'best practice' outweighs the 'not recommendable' practice, so that scores range between -0.5 and 0.8, and they are distributed around a midpoint of about 0.3. This can be seen from Figure 6.1, which shows the distribution of the scores. Only four schemes obtained a score that was below zero, three in Poland and one in Malta.

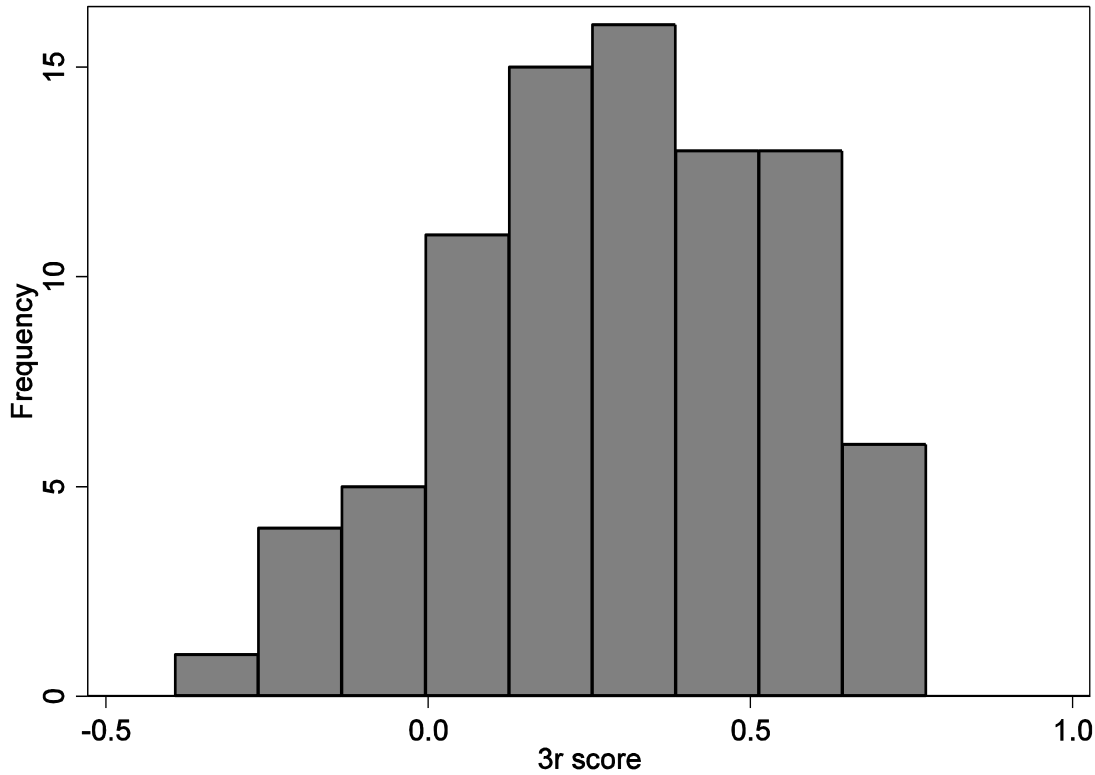
Here, t_i is the overall score of instrument i, and s, t, o are the scores on scope, targeting, and organization. Variables with a bar are mean values over instruments.

41 The *3r* rating score obtained is a rudimentary measure of the best practices of the tax instruments. Unfortunately, the collected information and empirical evidence on the R&D tax incentives do not admit further differentiation, thus making any more detailed modelling inappropriate. Nevertheless, the 3r score provides a marked differentiation between the R&D tax instruments and hence can be applied for benchmarking.

42 If missing values are excluded from the calculation of the mean, then the result is S/v where S is the sum of ratings of $v \leq 20$ valid variables; if missing values are treated as zeros, then the resulting score is $S/20 = S/v * v/20 = S/v * \left(1 - \frac{m}{20}\right)$, i.e. the score based on valid variables is 'discounted' by 1/20th for each of the m missing variables ($v + m = 20$). The score calculated is reduced by 5% for each missing value. The effect of missing values on the calculations is not large: data on at least 15 out of a possible 20 variables is available for more than 84% of R&D tax instruments, and a third of instruments are benchmarked on the basis of 18 or more variables.

43 If such 'discounting' is not applied, the results seem to be overly inflated. For all but four of the tax instruments the *3r* score was greater than zero.

Figure 6.1 Histogram of benchmarked 3r scores

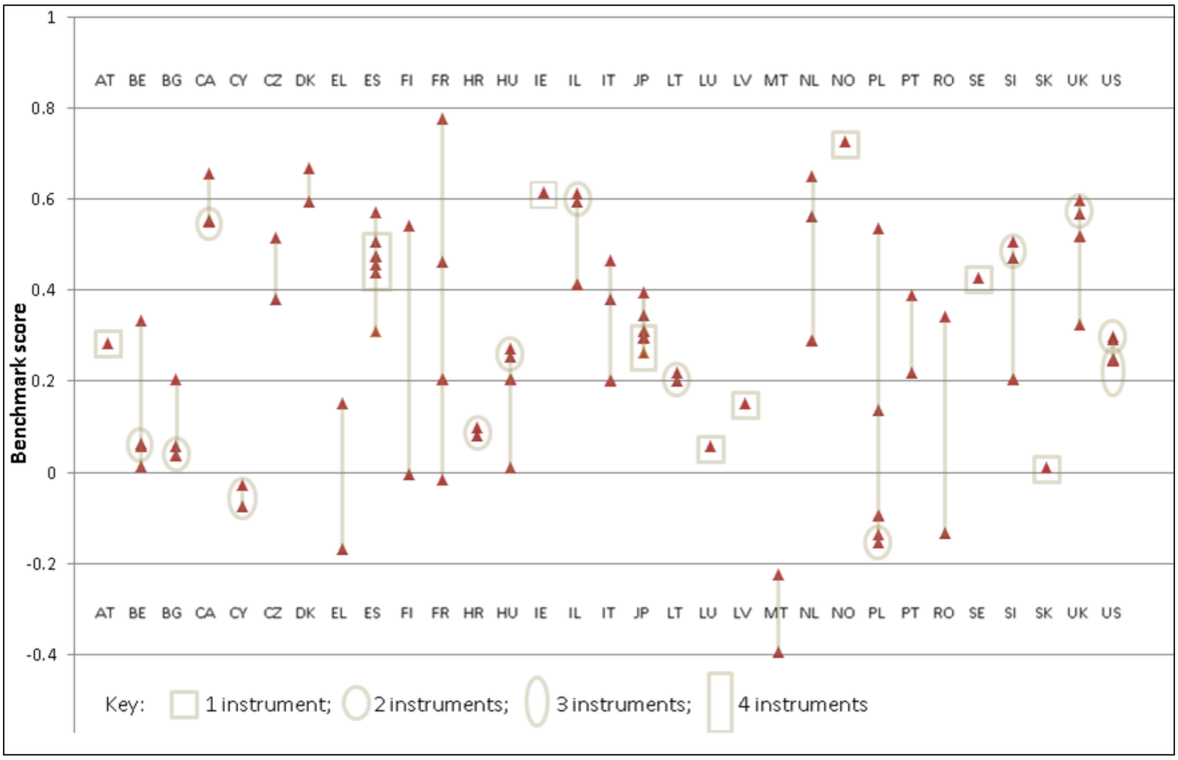


6.3 Benchmarking results

In order to get a first impression of best practices within countries, Figure 6.3 shows the scores for each instrument by country (most countries have more than one R&D tax incentive). When there are several instruments that have the same score, this is indicated. As can be seen fromFigure 6.3, the scores vary greatly within some countries. France and Poland, for example, have instruments that score very high and they have instruments that have a score of zero or even smaller. The figure also shows that countries could also improve by adopting good practices from their own country.

When the benchmarking scores are averaged by countries, almost all countries have a positive average score, which indicates that good practices are more prevalent than non-recommended practices. The country with the overall highest average ranking is Norway, which has one instrument- the SkatteFUNN. It has high scores on the scope and organization. Second comes Denmark (two instruments), which is mainly driven by its high score on organization of the tax incentive schemes, and Ireland (one instrument- the R&D tax credit) that performs well in terms targeting and organization. The better performing countries score about 0.5 or higher, while the least performing countries have scores below 0.1 (more detail on the benchmarking results for countries is provided in the Annex).

Figure 6.2 Dispersion of benchmark scores per country



Note: Estonia and Germany were not included in benchmarking as they do not offer any type of R&D tax incentives (see Annex with country fiches for more details)

The ten R&D tax incentives with the best overall benchmarking scores are displayed in Table 6.2 (a ranking of all instruments can be found in the Annex). The French tax credit for young innovative enterprises (Jeunes Entreprises Innovantes, JEI) tops the list. This tax incentive has the highest score on scope and ranks third in terms of organization. The JEI scheme is targeted towards young innovative firms that are less than eight years old, that are legally independent, and for which R&D expenditure is at least fifteen percent of the total expenses.

For JEI, R&D is defined according to OECD Frascati Manual, and includes basic and applied research, as well as experimental development. The novelty requirement is "new to the world", which is considered best practice. A wide range of expenditures, including R&D personnel costs, a fixed share of operating costs, qualified outsourced activities and costs of obtaining and maintaining IPR, qualify as R&D expenditure.[44]

The scheme does not differentiate in terms of sectors and geography. Firms can receive an immediate refund and benefit from the scheme even if they operate with no taxable income, which is especially important aspect for the target group of the instrument. Currently, an application form can be downloaded from a website and then it must be sent by post to a specific department. The response time for an application is set at maximum of three months. A more detailed description of the JEI scheme can be found in the Annex.

[44] Senat, Projet de loi de finances pour 2014 : Recherche et enseignement supérieur. Accessed on August, 2014. *Availabe at:* www.senat.fr/rap/l13-156-322/l13-156-32221.html#fn90

Table 6.2 Ranking of R&D tax incentives - top 10

Instrument name	Country	Overall rank (score)		Scope rank (score)		Targeting rank (score)		Organization rank (score)	
Jeunes Entreprises Innovantes	FR	1	(0.78)	1	(1.00)	16	(0.67)	3	(0.60)
SkatteFUNN	NO	2	(0.73)	23	(0.40)	61	(0.39)	1	(0.80)
Accelerated amortization	DK	3	(0.67)	66	(-0.10)	5	(0.78)	1	(0.80)
SR&ED	CA	4	(0.66)	3	(0.80)	50	(0.44)	14	(0.55)
WBSO	NL	5	(0.65)	8	(0.60)	48	(0.50)	3	(0.60)
R&D Tax Credit	IE	6	(0.61)	47	(0.27)	5	(0.78)	3	(0.60)
Capital Investments	IL	7	(0.61)	23	(0.40)	37	(0.56)	3	(0.60)
R&D Relief	UK	8	(0.60)	8	(0.60)	36	(0.61)	15	(0.50)
Skattekreditordningen	DK	9	(0.59)	23	(0.40)	50	(0.44)	3	(0.60)
R&D tax allowance	IL	9	(0.59)	23	(0.40)	50	(0.44)	3	(0.60)

Note: a ranking of all instruments can be found in the Annex

The Norwegian SkatteFUNN tax credit comes second, driven by its first place for organizational practice. The SkatteFUNN R&D tax credits are volume-based and apply to R&D expenditure as defined in the OECD Frascati Manual. While a preferential rate is offered to SMEs, the scheme does not differentiate across regions or sectors. Carry-over is not possible, but firms receive a cash-back when they do not have taxable income or if the tax benefit exceeds the tax payable by the firm (in this case, the difference is paid out). In terms of organization, the application procedure for SkatteFUNN is based on self-declaration and can be carried out online. Advice and guidance throughout the application can be received from the relevant authorities. The online application form provides explanations for all covered questions, and an example of a filled application is available online.

In order to decrease the uncertainty about eligibility for firms, Innovasjon Norge (*Innovation Norway*) makes a pre-assessment of whether the project qualifies for support or not. Forskningsrådet (The Research Council of Norway) approves or disapproves the application. Skatteetaten (Skattedirektoratet, Directorate of taxes) finally makes the decision about the amount of the tax benefit. In case of a positive response, the benefit is paid out in the year after the investment in R&D took place.

SkatteFUNN has been evaluated on several occasions. There have been evaluations of its impact on R&D expenditure, its effect on innovative activity, and of the interaction with direct R&D policy instruments[45]

Canada's Scientific Research and Experimental Development Tax Incentive Program (SR&ED) rates fourth. SR&ED is a volume-base R&D tax credit that, in accordance with Frascati Manual, applies to experimental, applied and basic research. The novelty requirement of R&D activities is "new to the world". As of 2014, the eligible costs include current expenditure such as wages, materials, outsourced activities (limited to 80 percent) and some overhead. Capital expenditure incurred after the end of 2013 does not qualify as eligible expenditure (Canada Revenue Agency (2014), *Who can claim SR&ED tax incentives and what are the benefits*?). For "Canadian-controlled private corporations" (CCPC) the tax credit is 35 percent refundable up to CAD 3

[45]See, for example, Hægeland and Møen (2007a; 2007b) and Cappelen et al. (2012)

million. Above that line, the tax credit is set at 15 percent and refundable only for small CCPC. Generally, the tax credit can be carried backward for 3 years and carried forward for 20 years.

Canada has a very thorough organization system. Firms are required to file the specific SR&ED claims along with income tax forms electronically. Different sorts of application assistance is available (First-time advisory service, SR&ED Self-assessment and Learning Tool, Preclaim Project Review, Account Executive Service (assign a contact person that assists in the process) and an assistance to resolve the claimant's concerns in case the entity does not agree with the results of a review). Furthermore, it is possible to subscribe for the SR&ED mailing list that informs about the different policy changes. The maximum time limit within which the claims should be processed is set out in "Service standards"; 120 days for refundable tax credits and 365 days for non-refundable. In practice, the response time is half of the planned time (Canada Revenue Agency (2014) *SR&ED Program Service Standards*). R&D tax credits in Canada have been evaluated both academically and by the government on several occasions. The impact on wide set of outcome variables have been assessed, including analysis on general welfare effects.[46]

The fifth position is taken by the Dutch payroll withholding tax credit (WBSO), which performs well in terms of scope and organization. The WBSO offers companies to reduce the wage bill of R&D personnel by lowering social insurance contributions and the wage tax. The R&D tax credit is also available for self-employed that are carrying R&D activities. The payroll withholding tax credits explicitly target human resources part of the innovation chain, where the largest externalities can stem from. Furthermore, the amount of the tax credit is not linked with the profitability position of the firm, as it is not set against the corporate tax. For non-personnel costs, a complimentary scheme (RDA) is available. WBSO provides support to development projects; technical and scientific research; analysis of the technical feasibility of in-house R&D; and process-oriented technical research. The rate of benefit decreases with the amount of expenditure (two brackets are set), which indirectly targets to firm size, as generally large firms tend to have larger R&D budgets. Additionally, for start-up companies the rate in the first bracket is higher than for the rest of firms.

In terms of organization, when firms complete the application, they are automatically guided through the process, with consultations available at the Netherlands Enterprise Agency, which administers the scheme. The description of the projects must be precise and measurable. The decision is made within three months. When a firm has been granted the tax credit, it is required to keep the administrative records of the relevant projects. Netherlands Enterprise Agency may hold an inspection within the firm to assure the validity of claims. In case the claims cannot be validated, the agency will correct the amount of benefit offered. Evaluations of the R&D tax credits are planned, and have been carried on regular bases. The evaluations have looked at wide set of impacts, both using quantitative and qualitative approaches.[47]

The top ten of R&D tax incentives is dominated by R&D tax credits: six tax credits are accompanied by two accelerated depreciation schemes and two enhanced allowances. Table 6.3 compares types of R&D tax incentives by their average scores. R&D tax credits, the most popular type of tax incentive for R&D, have a higher overall score than other types of instruments (with the exception of the small category of hybrid instruments). Tax credits distinguish themselves from enhanced allowances and

[46]See, for example,Baghana and Mohnen (2009), Czarnitzki et al.(2011), Parsons and Phillips (2007)

[47]See, for example,Lokshin and Mohnen (2008, 2009, 2012), Verhoeven et al. (2012), Cornet and Vroomen (2005)

facilities for accelerated depreciation primarily because of their higher scores on scope. Patent boxes, with an average overall score close to zero, are on the bottom of the list. The reason for this is the strongly negative score on the scope of the incentive type.

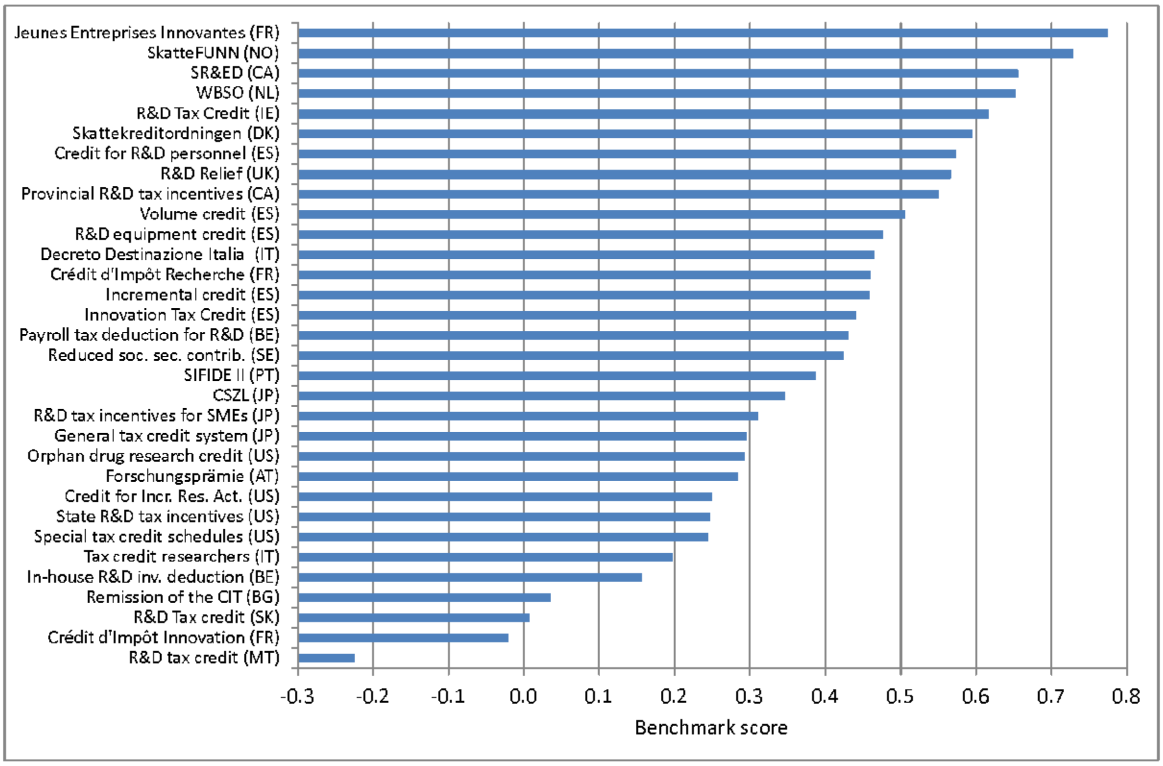
All types of tax incentives have relatively low average scores on organization, which mostly stems from not having (planned) evaluations and public consultations, as well as long decision period. This suggests that there is substantial room for improvement across all instrument types. The outcomes for targeting are relatively high (schemes are rather generic and many offer a carry-over facility and a 'negative tax' option), while the results for the scope seem to vary systematically with the type of instrument.

Table 6.3 Average benchmark score per type of tax incentive

Type of tax incentive	Overall	Scope	Targeting	Organization
Hybrid: enhanced allowance and accelerated depreciation	0.40	0.60	0.72	0.20
Tax credit	0.38	0.47	0.54	0.25
Enhanced allowance	0.30	0.33	0.53	0.19
Accelerated depreciation	0.28	0.34	0.60	0.15
Reduced tax rate	0.14	-0.20	0.30	0.20
Patent box	0.08	-0.35	0.52	0.11

Figure 6.3Figure 6.3 compares the overall scores for all R&D tax credit schemes. The high average score of tax credits is due to a large number of well scoring instruments: about half of the R&D tax credits have a score exceeding 0.4.

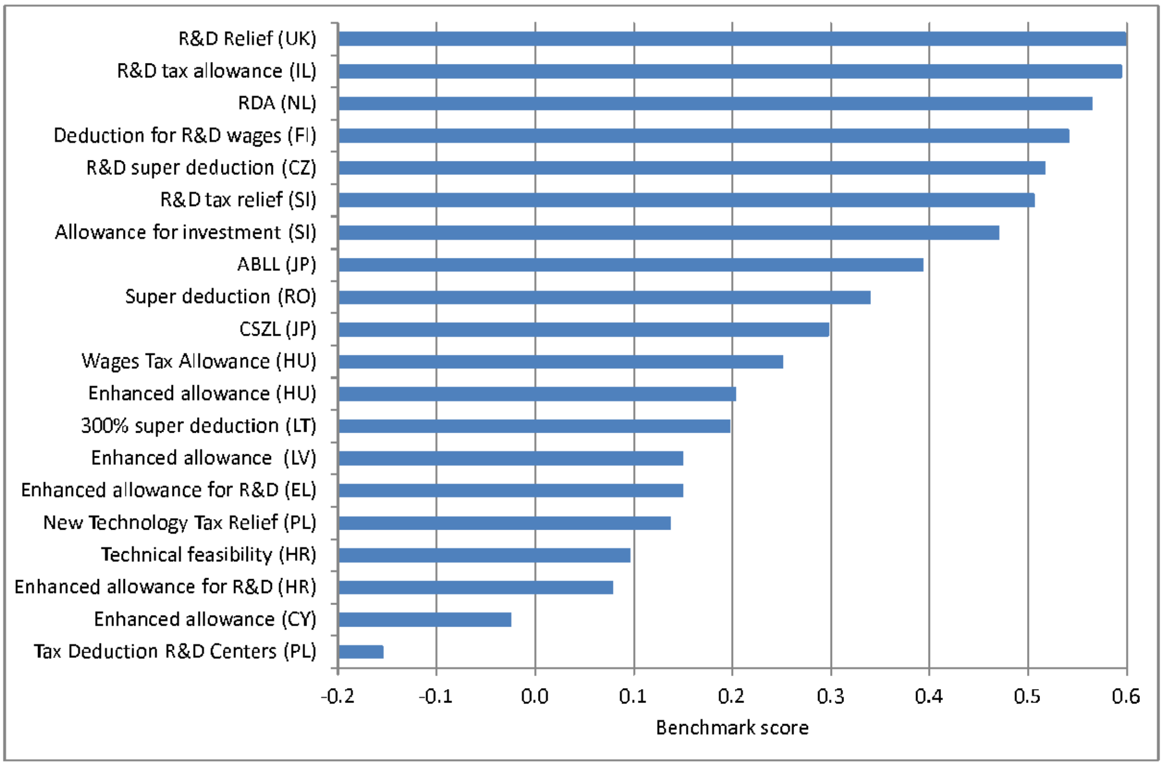
Figure 6.3 Benchmark scores for R&D tax credits



Enhanced allowances also score relatively high across the board (Figure 6.4). British R&D Relief and the Israeli R&D tax allowance are the most highly ranked enhanced allowances (see Table 6.4). United Kingdom's R&D tax relief is a tax allowance that reduces taxable corporate income by an amount that is proportional to R&D expenditure. For tax purposes, the enhanced allowance either reduces the firm's profit, or increases its losses. The definition of R&D is similar to the one in OECD Frascati Manual; only activities that seek advancement in the overall knowledge qualify. Eligible costs include current expenditure, while for capital expenditure an accelerated depreciation is offered. The R&D relief is separated into scheme for SMEs and large companies, being more generous for the former group.[48] SMEs are offered a higher rate of the enhanced allowance, and they are able to receive the tax allowance in cash in case they do not have taxable income.

The R&D schemes in United Kingdom also perform well in terms of organization. Similarly, as in other good practice cases, an online application and a one-stop agency is available. Information about the design of the scheme, eligibility and application requirements, as well as policy changes, is easily accessible online. The schemes are reviewed through public consultations, and necessary amendments are taken place after the views have been received. This encourages schemes to be up-to-date and to offer better value for tax money. Furthermore, the government has also carried an evaluation of the scheme, using both quantitative and qualitative approach.[49] Every year Office of National Statistics (ONS) publishes a bulletin with information about the number and type of beneficiaries.

Figure 6.4 Benchmark scores for enhanced allowances for R&D



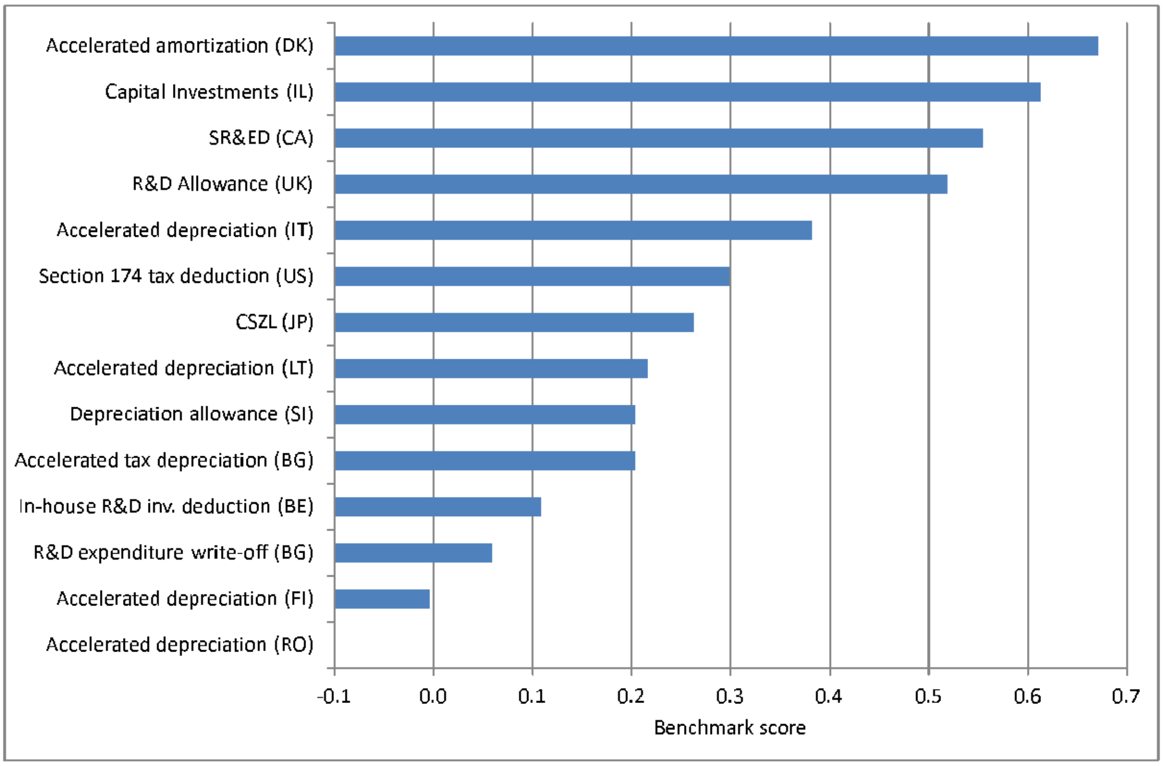
[48]The current enhanced allowance for large companies will be fully replaced by the new 'Above the line' tax credit in 2016

[49] See: HMRC (2010)

More detailed discussions of selected good practice R&D tax schemes are provided as good practice cases which are supplied in the Annex. A complete ranking of instruments can also be found in the Annex.

Figure 6.5 displays the scores for accelerated depreciation. The accelerated depreciation scheme with the highest overall score is the Danish Accelerated Amortization, followed by the Israeli Capital Investments scheme. For both schemes the high ranking stems from the good organizational practice. In both cases, the decision time for applications of R&D tax incentives is very short (less than two- three months). A one-stop agency and an online application are available. More detailed discussions of selected good practice R&D tax schemes are provided as good practice cases contained in the appendix. A complete ranking of instruments can also be found in the appendix.

Figure 6.5 Benchmark scores accelerated depreciation



6.4 Data availability

Evaluation of an individual policy instrument requires high-quality firm-level data. The Expert Group on R&D Tax Incentives Evaluation concluded that both data and methodologies need to be comparable across countries in order to be able to assess the effectiveness of policy instruments (European Commission, 2008). Otherwise, it will remain difficult to assess whether differences in outcomes reflect differences in the effects of policy instruments. Access to firm-level data for researchers is a first step in this direction.

Currently, firm-level data can be accessed in 24 of the analysed countries (see Table 6.4). For comparability of results it is important that all countries use the same definition of variables. At the most basic level this requires that countries align with Eurostat or OECD norms. This seems to be the case for all countries. 22 countries participate in the Community Innovation Survey (CIS), a survey that collects firm-level data on innovation and R&D, including expenditure on innovation and public support.

Although basic ingredients for firm-level evaluation studies seem in place, few countries perform regular evaluations. For about half of the countries, an evaluation of an R&D tax incentive has been performed in the past.

Table 6.4 Data availability per country

Country	Firm level data	Eurostat/ OECD norm	CIS survey	Evaluation planned	Evaluation done
Austria	x	x			x
Belgium	x	x		x	x
Bulgaria	x	x	x		
Canada	x	x	n.a.		x
Croatia	x	x	x		x
Cyprus	x	x	x		
Czech Republic	x	x	x		
Denmark	x	x		x	
Estonia	x	x	x	n.a.	n.a.
Finland	x	x	x	x	
France	x	x	x	x	x
Germany	x	x	x	n.a.	n.a.
Greece		x[a]			
Hungary	x	x	x		
Ireland	x	x	x		x
Israel	x	x	n.a.		
Italy	x	x	x		x
Japan	x	x	n.a.		x
Latvia	x	x	x		
Lithuania	x	x	x		
Luxembourg	x	x	x		
Malta		x			
Netherlands	x	x	x	x	x
Norway	x	x	x	x	x
Poland		x			
Portugal	x	x	x		x
Romania	x	x	x		
Slovak Republic	x	x	x		
Slovenia		x	x		
Spain	x	x	x		x
Sweden	x	x	x		
United Kingdom	x	x			x
United States	x	x	n.a.		x

Notes: n.a. is not applicable; [a]breaks in the data from 2008 to 2010

6.5 Limitations of benchmarking

The benchmarking procedure has various limitations. First, the number of variables available for benchmarking is limited and those variables only partly contribute to the success of the scheme. They cannot capture such aspects as the 'easiness' of application in terms of how much paper work a firm has to do to apply to the scheme. It also cannot capture the general perception of the government or public program as such that may influence the take-up rates (e.g., it can be perceived that applying to a scheme is too complicated process or simply there is no broad information of the availability of the scheme).

Second, no systematic information is available on the accuracy of the administration: proper auditing of firms is needed in order to safeguard the scheme's effectiveness and efficiency. Those aspects, among other things, can be essential for the impact of the instrument. The benchmarking exercise should be viewed only with respect to the elements analysed.

Third, as the best practice principles are based on empirical evidence as well as theoretical considerations, future evidence might lead to different judgements. The benchmarking results should be taken as a first indication.

We have chosen a straightforward way to compute an overall score, but more advanced techniques are available, such as Data Envelopment Analysis. Decancq and Lugo (2013) give an overview of different techniques. Also, different choices can be made on how to weigh the scores per principle. A robustness analysis for the weighting scheme has been added to the Annex on Methodology. Different weighting schemes do not lead to very different outcomes. Probably the largest challenge lies in collecting more data on how schemes work in practice, rather than employing more advanced techniques.

6.6 Summary of good practice cases

In order to provide a more in-depth overview of what constitutes good practice, ten R&D tax incentives were studied in more detail. The selection criteria are a mix of the following three elements: (a) the tax scheme has a high benchmarking score; (b) it represents a novel (and promising) approach in view of the "principles for good practice" discussed above; and (c) different combinations of R&D tax incentive schemes and innovation systems are represented. The reasons of selecting each specific scheme is discussed in more detail below.

The schemes that were selected for the good practice case studies are: Canada's SR&ED, the United Kingdom's R&D relief, the Danish Skattekreditordningen, Norway's SkatteFUNN, France's Jeune Entreprise Innovante, the Dutch WBSO, Ireland's R&D tax credit, Spain's Incentivos fiscales a la I+D+i[50], Croatia's Enhanced allowance for R&D and France's Crédit d'Impôt Innovation. A summary of key points is provided in Table 6.5, the ten full case studies can be found in the Annex.

SR&ED tax credit (Canada)

Canada's *SR&ED tax credit* was one of the first R&D tax credit systems in the world. It has undergone various reforms and currently is a volume-based R&D tax credit, which offers a preferential rate to local small companies.

The scheme has one of the most comprehensive administration practices. The tax measure has been evaluated both academically and by the government on several occasions (including an analysis on general welfare effects). Additionally, the design of

[50] In benchmarking, named separately as "volume credit", "incremental credit" and "credit for R&D personnel".

Canada's R&D tax credit has been very stable, which greatly increases the firms' familiarity with the tax credit.

R&D tax relief schemes (United Kingdom)

Another example of good practice is the United Kingdom's *R&D tax relief schemes*. All relevant information is easily accessible online and several "help points" are available, where firms can turn for advice on their R&D claims. The policy is reviewed through public consultations, and government has also carried an evaluation of the tax policy.

In addition, United Kingdom has a good practice in terms of "novelty requirement" for R&D activities, which is new to the world: only those activities that promote the overall knowledge or capability are supported. This approach is also adopted in other good practice cases discussed (Canada, France, Ireland, Spain and Croatia).

Enhanced allowance for R&D (Croatia)

Croatia's *Enhanced allowance for R&D* stands out because it links the super deduction rate with the type of R&D (fundamental, industrial or applied research). Projects that have higher level of novelty receive a higher relative tax benefits and vice versa. The option to receive a tax benefit for technical feasibility projects (first stage of an R&D project) can be important for more financially constrained firms that see opportunities for R&D.

The R&D tax allowance in Croatia also has adopted a good practice for evaluation. While the scheme was introduced only in 2007, it has already been evaluated several times, both using quantitative and qualitative analysis. To our knowledge, Croatia is the only new EU-member state that has undertaken such evaluation.

Skattekreditordningen (Denmark)

Several schemes provide the option to receive a tax benefit even when a firm makes a loss. The aim of this approach is to provide benefit to younger R&D companies that generally do not make profits in the first years of operations. In this category Denmark's *Skattekreditordningen* is a unique scheme , as it targets support only to those R&D firms that have negative gross profits. Skattekreditordningen is intended to be a temporary measure in times of economic recession when access to finance is more limited. In this way, the policy instrument intends to compensate for a temporary lack of access to external finance.

Skattekreditordningen presents a good administration practice. The application procedure can be settled online and a one-stop agency is available. Another positive aspect of the general organization practice is that the Danish tax policy instruments are assessed regularly. Less positive is the long period of before actual reimbursement of the tax credit that can take up to two years.

Jeunes Entreprises Innovantes (France)

An example of an explicit targeting towards young innovative companies is France's *Jeunes Entreprises Innovantes* (Young innovative enterprise-JEI) R&D tax credit. It provides generous support to young SMEs for which R&D expenditure represents at least fifteen percent of total costs. The novelty requirement of R&D is according to best practice ("new to the world").

The immediate refund option and short response time means that firms can obtain the funding faster. Firms can enjoy the benefits only for eight years, assuring that the generous support is given only at early stages of business development.

JEI has been evaluated, with studies concluding that the scheme had a positive impact on R&D activities and the general performance of firms.

WBSO (The Netherlands)

Another scheme that provides additional support to start-ups is the Dutch *WBSO*. The WBSO is a volume-base payroll withholding tax credit. The rate of the credit decreases in expenditure claimed, with two brackets set. Within the first bracket (up to EUR 250,000), young companies receive a 50 percent tax credit, while all other firms receive 35 percent. The rate in the second bracket above EUR 250,000 is homogenous across groups.

WBSO also presents a well-developed administration. Application is carried online, a one-stop agency is available and the decision of the refund is made within three months. Additionally, the evaluations for WBSO are planned and frequent, and studies involve both quantitative and qualitative assessments.

SkatteFUNN (Norway)

Norway's R&D tax credit *SkatteFUNN* is largely generic and only offers a preferential rate to SMEs. In the benchmarking exercise, SkatteFUNN ranks especially high in terms of organization. The application procedure of the R&D tax credit is quite simple: firms can apply online, one-stop agency is available and several guides are available.

Furthermore, the introduction of the policy involved a public consultation and it has been evaluated various times. Due to those evaluations, a special database with time-series data on firm level was constructed, which promotes replication of results and further studies, which is a good practice that other countries should consider implementing.

R&D tax credit (Ireland)

The *R&D tax credit* in Ireland has a generic nature, covering a wide scope of eligible expenditures and offering a common rate to all types of firms, including foreign companies. This is important for a small and open economy like Ireland, as it maintains a level playing field for foreign direct investment (FDI) inflows and facilitates knowledge transfer from innovative multinationals.

The scheme's organization conforms best practice. The application procedure is relatively simple, offering an online application, a one-stop agency and guides. Even though an econometrical evaluation of the effects of the R&D tax credits was deemed impossible, consultation and survey of firms indicated that the R&D tax credit system is viewed as beneficial to motivating more R&D in the private sector.

Incentivos fiscales a la I+D+i (Spain)The high ranking of Spain's R&D tax incentives in the benchmarking exercise have largely been induced by recent policy changes, which are the main reason for highlighting Spain's experience. Currently, Spain's R&D tax credit system is one of the most generic. It is not explicitly targeted to any particular size of the firm, region or activity, which is an advisable approach. The recently introduced option to receive a cash-refund and to carry over all or part of the R&D expenditure, gives firms more flexibility in their investment decisions, which is especially important for young firms. Entities can apply online and receive a pre-validation of the qualifying expenses that lowers the compliance costs of firms. Annual guides on the tax incentive and a one-stop agency are also available.

Crédit d'Impôt Innovation (France)

The tenth good practice case is France's *Crédit d'Impôt Innovation* (Innovation tax credit, CII) which has a new approach in terms of eligible expenses. CII exclusively offers a tax benefit for downstream R&D activities (e.g., prototyping and pilot assets). Such costs may not fit into the general definition of R&D and normally would be excluded from the eligible expenditure of R&D tax incentives, but creation of prototypes and pilot studies are part of the innovation process. A strong capacity for prototyping is cost- and time-efficient way for firms to try and experiment new ideas before actually launching them in the market. Building a prototype or a pilot project can also be used as a demonstration tool for investors, which is especially useful for young start-up companies.

Table 6.5 Summary of selected good practice cases

Name	Type	Novelty	Target	Cash refund	Carry over	Application	Evaluation
R&D Relief (UK)	volume enhanced allowance	new to world	size	yes	cf	online; one-stop; refund within year	yes (gov.)
Skattekreditordningen (DK)	volume tax credit	new to firm	liquidity	yes	no	online; one-stop; refund next year	planned
SkatteFUNN (NO)	volume tax credit	new to firm	size	yes	no	online; One-stop; refund within year	yes (gov. & acad.)
Jeune Entreprise Innovante (FR)	volume tax credit	new to world	size/age	yes		paper; pre-approval < 3 months, immediate refund	Yes (gov.)
WBSO (NL)	volume payroll withhold. tax credit	new to firm	implicit size, explicit age	n.a.	n.a.	online, one-stop; pre-approval < 3 months; immediate refund	yes (gov. & acad.)
R&D Tax Credit (IE)	incremental / volume tax credit	new to world	No	yes	cb & cf	online, one-stop, refund within year	yes (gov.)
SR&ED (Canada)	volume tax credit	new to world	size, local firms	yes	cb & cf	online; one-stop, decision < 120 (365) days	Yes (gov. & acad.)
Incentivos fiscales a la I+D+i (ES)	volume & incremental tax credit	new to world	No	yes	cf	online, one-stop, pre-approval, immediate refund	yes (acad.)
Enhanced allowance for R&D (HR)	volume enhanced allowance	new to world	size, novelty	No	cf	paper, refund next year	yes (gov.& acad.)
Crédit d'Impôt Innovation (FR)	volume tax credit	new to world	size	yes	cf	paper; pre-approval < 3 months, immediate refund	planned

Notes: Carry forward (cf); carry back (cb); government evaluation (gov.); academic evaluation; (acad.); not applicable (n.a.). The full description of the good practice cases is provided in the Annex.

7 Conclusions

As part of the Europe 2020 strategy for growth, European investment in R&D should reach at least three percent of GDP by the year 2020. The financial crisis has impacted the course for reaching the target in two ways. First, the financial crisis obliged many governments to introduce tough fiscal consolidation measures, prioritizing other issues over R&D. Second, the drop in economic activity put even more emphasis on the need to find new sources of growth. Both developments have spurred interest in the effectiveness of R&D tax incentives.

What kinds of R&D tax incentives are being used?

The overview of R&D tax incentive schemes presented in this report reveals that 26 EU member states currently have some type of fiscal encouragement for R&D. R&D tax incentives are also offered by the OECD countries analysed in this report: Canada, Israel, Japan, Norway and the United States.

Tax incentives for R&D differ substantially across countries, with the majority of countries having more than one type of incentive. Most tax incentives apply on corporate income taxes. In eight countries the benefit is also set against social contribution and/or wage taxes.

Tax credits for R&D expenditure are the most common type of R&D tax incentive, enhanced allowances for expenditure on R&D come second, and accelerated depreciation third. Tax benefits for income from innovation, patents boxes, are becoming more popular as well.

Most tax incentives apply to the total amount of R&D expenditure (volume-based R&D tax incentives). Currently, only seven countries offer incremental R&D tax schemes, for whom tax benefit applies only to the increment of the R&D expenditure. In Ireland and the United States this design element is being phasing out.

R&D tax incentives often target specific groups of firms. Targeting on the size and age of firms are the most common approaches: in ten countries more generous support is offered to small- and medium-sized enterprises and in six countries- to young firms (e.g., Belgium, France and The Netherlands, among others). Most countries put a ceiling on the amount that firms can receive and in five countries the generosity of the scheme decreases with the size of a firm’s R&D expenditure. This approach indirectly provides more generous support to smaller firms, which typically have smaller R&D budgets.

Cluster analysis showed that some countries are more similar with respect to their policies than others. The most similar pairs of countries were Denmark and Norway, Portugal and the United States, and Ireland and Spain. Sweden has an R&D tax incentives scheme that is the most different from other schemes.

Do R&D tax credits work?

Impact on R&D expenditure, innovation and productivity

The report covers a large body of literature assessing the impact of R&D tax credits. The vast majority of studies surveyed concludes that R&D tax credits spur investment in R&D. The estimates of the size of this effect are widely diverging and not always comparable across methodologies. The wide range of results probably reflects differences in methodology as well as differences between countries and policies, but is difficult to disentangle those effects. Studies that are more rigorous econometrically and yield more precise estimates find that one euro of foregone tax revenue on R&D tax credits raises expenditure on R&D by less than one euro (Cornet and Vroomen, 2005; European Commission, 2008; Lokshin and Mohnen, 2012; Mulkay and Mairesse, 2013).

The impact of R&D tax credits on R&D expenditure is informative on the effectiveness of R&D tax credits, but this is only a part of the puzzle. A second piece of the puzzle is the answer to the question whether R&D tax credits make firms more innovative and productive. The impact of R&D tax incentives on innovation and productivity by firms receiving those benefits, however, is less studied. R&D tax incentives appear to have a positive impact on innovation, although none of the studies has used exogenous variation to verify the causality of the relation. As the most profitable R&D projects are likely to be performed regardless of tax benefits, it might be the case that R&D projects induced by tax incentives are project of below average quality. Another possibility is that projects are less profitable because they generate large knowledge spillovers. In this situation, R&D tax incentives might stimulate projects with above average knowledge spillovers.

Payroll withholding tax credits may have an upward effect on the wages of R&D workers (Cornet and Vroomen, 2005; Lokshin and Mohnen, 2013). Goolsbee (1998) found the same effect for total government expenditure on R&D. This is additional evidence of the effectiveness of tax credits: a rise in demand is expected to lead to higher prices in most markets.

Impact heterogeneity

The effects of R&D tax incentives vary across sub-groups of firms, with most studies focusing on firm size. The results seem to differ across countries, which makes it difficult to draw clear conclusions. In some of the countries analysed, SMEs tend to respond more strongly to the support for R&D, while the reverse was found in other countries. These seemingly contradictory results make it difficult to draw general conclusions. There is some evidence that the impact for start-up firms can exceed the average impact, but in general, there is not much evidence on how effectiveness of tax incentives varies with firm age. There is a clear literature gap in identifying whether the impact differs across firms with different legal status.

What are the welfare effects?

Estimates of the social rate of return to R&D are variable and imprecise but tend to exceed estimates of the private rate of return to R&D (Hall *et al.*, 2009). This indicates that there is a scope for innovation policy to raise welfare. Recent evidence suggests that knowledge spillovers of large firms exceed those of small firms (2013). This finding provides an argument against targeting tax incentives towards SMEs. On the other hand, SMEs tend to respond more strongly to R&D tax incentives, which suggests that targeting on SMEs still could be efficient.

Social cost-benefit analyses for The Netherlands, Canada and Japan showed that R&D tax credits can have positive welfare effects but that this outcome is highly sensitive to assumptions (Parsons and Phillips, 2007; Russo, 2004; Ghosh, 2007; Mohnen and Lokshin, 2008; Cornet, 2001; Diao *et al.*, 1999).

Design and interaction between instruments

The impact of R&D tax credits may be highly sensitive to their design and organization. The different results found for SMEs across countries are indicative of this. However, evidence on the effects of design features is inconclusive for some features, while for evidence is lacking altogether for other features. An important aspect of R&D tax credits is whether they apply to incremental R&D expenditure or whether they are "volume-based". Both kinds of designs have been evaluated, and both of them have been found to result in additional R&D expenditure. The variation in estimates across studies is too large to be able to conclude that there is a statistically significant difference between the effectiveness of incremental and volume-based schemes.

The optimal generosity of a tax credit is ambiguous. A small government budget for the tax incentive might not provide sufficient incentives for additional R&D due to compliance costs. Also large budgets might be ineffective. The marginal impact of a tax incentive might decrease as the budget gets large. Very generous schemes might lose their focus and will effectively only reduce the corporate income tax rate. More generous R&D tax incentives also appear to be associated with narrower growth distribution in R&D intensive sectors, that may lead to an enhancement of incumbent firms (Bravo-Biosca *et al.*, 2013). This also shows that the design of R&D tax incentives should necessary consider the needs of young firms. This may include an option for cash-refunds when profits and carry-over provisions are absent.

Findings from studies that looked at the interaction between tax incentives for R&D and subsidies, showed that tax incentives and direct subsidies need to be well balanced and integrated. As such, perverse incentives through "double counting" of R&D expenditure could be avoided. If the subsidies and R&D tax incentives are designed in a way to complement each other, this may also provide additional support to activities that, from the government's perspective, have the highest social returns.

Whether R&D tax incentive schemes targeted at cooperation between firms or public research institutes lead to higher additionality, is understudied. Research cooperation between competitor companies is shown to lead to collusive outcomes in the product market (Duso T. *et al.*, 2014).

Do patent boxes work?

A large body of literature has identified that multinational firms increasingly engage in profit-shifting activities in order to decrease the overall tax liabilities. Intangible assets, like patents, play an important role as they are relatively easy to move from one location to other. In addition, for large firms innovation often is an international activity: firms may perform R&D in one country, patent the product in another and commercialize it in a third one. Studies show that a strong negative relation persists between corporate income tax and the number of patents registered in a country. Patents with a higher potential profitability appear to be especially sensitive to corporate income taxes.

Simulations show that tax competition using patent boxes will result in large decreases in tax revenue for all governments engaging in such a policy (Griffith *et al.*, 2014). Furthermore, it is hard to make the argument why a patent box would reduce market failure caused by knowledge spillovers: patent boxes introduce a preferential rate for income from innovations that are already protected by IPR. The impact on innovation of patent boxes is difficult to evaluate empirically as tax planning and tax competition induce measurement error in innovation indicators.

Other issues

Several innovative countries have no R&D tax incentives or implemented them only recently. Germany and Estonia - the country with largest increase in innovative performance between 2006 and 2013[51] - do not have R&D tax incentives. This indicates that R&D tax incentives are not required for an innovative economy, but they might support it.

R&D tax incentives are essentially designed to promote R&D, as defined in statistical offices (OECD, 2002). However, many innovating firms invest in activities that are not

[51] Innovation Union Scoreboard (2014).

considered as R&D, including investments in software, large data sets, designs, firm-specific human capital, and new organizational processes. This implies that fiscal support for innovation biased against innovative companies without formal R&D activities.

Methodological and data limitations remain substantial and high-quality evaluation studies are unavailable for many countries. This leads to gaps in the literature on how the effectiveness of R&D tax incentives depends on their design and organization as well as on country characteristics. Replication of studies for multiple countries can help to close these gaps.

Best practices

Comparing the effectiveness of R&D tax incentives across countries is a challenging task. Most R&D tax incentives have not been evaluated quantitatively, making it impossible to compare them directly. When an evaluation study is available, it is difficult to compare the results with other evaluations as evaluation studies differ wildly in their methodology. Moreover, similar R&D tax incentives might have very different impacts due to differences in framework conditions.

In the absence of comparable evidence on the performance of specific R&D tax incentives, more than 80 tax incentives in 31 countries have been benchmarked. The benchmarking is based on twenty *principles of best practice.*

The scores of tax incentives on the twenty best practice principles have be used to compute an overall index. The instrument that has the highest overall benchmarking score is the French tax credit for young innovative enterprises (Jeunes Entreprises Innovantes), due to high scores on scope and organization. The Norwegian SkatteFUNN tax credit comes second, mainly because of its first place for organization. The third position is taken by the Accelerated amortization in Denmark, with high scores on targeting and organization.

Overall, the eighty R&D tax incentives show substantial heterogeneity in their designs and organizational practice. Tax credits distinguish themselves from enhanced allowances and facilities for accelerated depreciation primarily because of their higher score on scope. Patent boxes have the smallest average score on scope. The heterogeneity of practices not only is present between types of tax incentives; differences among schemes of the same type are also large.

Heterogeneity in the features of tax incentives is likely to reflect differences in country characteristics (like innovation systems and tax rates), but also within countries there is sometimes a large discrepancy between the highest ranked instrument and the instrument with the lowest rank. This suggests that there are substantial opportunities for improving R&D tax incentives across the European Union - in particular with respect to the organization and scope of the tax incentives.

References

Aghion, P. and P. Howitt, 1992, A Model of Growth through Creative Destruction, *Econometrica*, vol. 60, no. 2, pp. 323-351.

Aralica Z., V. Botric and S. Švaljek, 2011, Evaluation of the Tax Incentives Aimed at Stimulation R&D Projects in the Business Sector, Working Paper Institute of Economics, Zagreb.

Aralica, Z. and V. Botriç, 2013, Evaluation of Research and Development Tax Incentives Scheme in Croatia, *Ekonomska istrazivanja*, vol. 26, no. 3, pp. 63-80.

Arrow, K., 1962, Economic welfare and the allocation of resources for invention, *The rate and direction of inventive activity: Economic and social factors,* NBER Chapters.

Atkeson, A. and A.T. Burstein, 2011, Aggregate Implications of Innovation Policy, *NBER Working Paper*, no. w17493.

Baghana, R. and P. Mohnen, 2009, Effectiveness of R&D tax incentives in small and large enterprises in Quebec, *Small Business Economics*, vol. 33, no. 1, pp. 91-107.

Berube, C. and P. Mohnen, 2009, Are firms that receive R&D subsidies more innovative?, *Canadian Journal of Economics/Revue canadienne d'économique*, vol. 42, no. 1, pp. 206-225.

Bloom, N., M. Schankerman and J. Van Reenen, 2013, Identifying technology spillovers and product market rivalry, *Econometrica*, vol. 81, no. 4, pp. 1347-1393.

Bloom, N., R. Griffith and J. Van Reenen, 2002, Do R&D tax credits work? Evidence from a panel of countries 1979 – 1997, *Journal of Public Economics*, vol. 85, no. 1, pp. 1-31.

Bohm, T., T. Karkinsky and N. Riedel, 2012, The Impact of Corporate Taxes on R&D and Patent Holdings, NBER Trans-Atlantic Public Economics Seminar of Business Taxation.

Bravo-Biosca, A., C. Criscuolo and C. Menon, 2013, What drives the dynamics of business growth?, OECD Science, Technology and Industry Policy Papers 1.

Busom, I., B. Corchuelo and E. Martínez-Ros, 2012, Tax incentives or subsidies for R&D?, *UNU-MERIT, Maastricht University School of Business and Economics*.

Caiumi, A., 2010, The evaluation of the effectiveness of tax expenditures: A novel approach, *ISAE Working Paper*, no. 126.

Caiumi, A., 2011, The Evaluation of the Effectiveness of Tax Expenditures- A Novel Approach: An Application to the Regional Tax Incentives for Business Investments in Italy, OECD Taxation Working Papers 5.

Cappelen, A., A. Raknerud and M. Rybalka, 2007, Effekter av SkatteFUNN pa foretakenes produktivitet og lonnsomhet, *Økonomiske analyser*, vol. 2007, no. 6, pp. -54.

Castellacci, F. and C. Lie, 2013, Do the effects of R&D tax credits vary across industries? A meta-regression analysis, *Munich Personal RePEc Archive No.47937*.

Cerulli, G. and B. Poti, 2012, Evaluating the robustness of the effect of public subsidies on firms' R&D: an application to Italy, *Journal of Applied Economics*, vol. 15, no. 2, pp. 287-320.

Cincera, M. and R. Veugelers, 2014, Differences in the rates of return to R&D for European and US young leading R&D firms, *Research Policy*, vol. 43, pp. 1413-1421.

Corchuelo, B. and E. Martinez-Ros, 2009, The Effects of Fiscal Incentives for R&D in Spain, Business Economics Working Papers wb092302.

Cornes, R. and T. Sandler, 1986, *The Theory of Externalities, Public Goods and Club Goods,* Cambridge University Press.

Cornet, M., 2001, De maatschappelijke kosten en baten van technologiesubsidies zoals de WBSO, CPB document (no.008).

Cornet, M. and B. Vroomen, 2005, Hoe effectief is extra fiscale stimulering van speur- en ontwikkelingswerk?Effectmeting op basis van de natuurlijk-experimentmethode, CPB document (no.103).

Czarnitzki, D. and C. Lopes Bento, 2011, Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany, ZEW Discussion Paper 11-053.

Czarnitzki, D. and C. Lopes-Bento, 2013, Value for money? New microeconometric evidence on public R&D grants in Flanders, *Research Policy*, vol. 42, no. 1, pp. 76-89.

Dagenais, M.G., P. Mohnen and P. Therrien, 1997, Do Canadian firms respond to fiscal incentives to research and development?, CIRANO Scientific Series.

Danguy, J., G. De Rassenfosse and B. Van Pottelsberghe de la Potterie, 2009, The R&D-patent relationship: An industry perspective, EIB papers 14.

David, P.A., B.H. Hall and A.A. Toole, 2000, Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence, *Research Policy*, vol. 29, no. 4-5, pp. 497-529.

De Jong, J.P.J. and W.H.J. Verhoeven, 2007, Evaluatie WBSO 2001-2005: effecten, doelgroepbereik en uitvoering, Ministerie van Economische Zaken.

De Mooij, R.A. and S. Ederveen, 2003, Taxation and foreign direct investment: a synthesis of empirical research, *International Tax and Public Finance*, vol. 10, no. 6, pp. 673-693.

Decancq, K. and M.A. Lugo, 2013, Weights in multidimensional indices of wellbeing: An overview, *Econometric Reviews*, vol. 32, no. 1, pp. 7-34.

Desai, M.A., C.F. Foley and J.R. Hines Jr, 2006, The demand for tax haven operations, *Journal of Public Economics*, vol. 90, no. 3, pp. 513-531.

Devereux, M.P. and R. Griffith, 2002, The impact of corporate taxation on the location of capital: a review, *Swedish Economic Policy Review*, vol. 9, no. 1, pp. 79-106.

Devereux, M.P. and G. Maffini, 2007, The impact of taxation on the location of capital, firms and profit: A survey of empirical evidence, Oxford University Centre for Business Taxation Working Paper Series.

Diao, X., T. Roe and E. Yeldan, 1999, Strategic policies and growth: An applied model of R&D-driven endogenous growth, *Journal of Development Economics*, vol. 60, no. 2, pp. 343-380.

Dischinger, M., B. Knoll and N. Riedel, 2014, The role of headquarters in multinational profit shifting strategies, International Tax and Public Finance 21.

Dischinger, M. and N. Riedel, 2011, Corporate taxes and the location of intangible assets within multinational firms, *Journal of Public Economics*, vol. 95, no. 7, pp. 691-707.

Doraszelski, U. and J. Jaumandreu, 2013, R&D and productivity: Estimating endogenous productivity, *The Review of Economic Studies*, vol. 80, no. 4, pp. 1338-1383.

Duguet, E., 2012, The effect of the incremental R&D tax credit on the private funding of R&D an econometric evaluation on french firm level data, *Revue d'économie politique*, vol. 122, no. 3, pp. 405-435.

Dumont, M., 2013, The impact of subsidies and fiscal incentives on corporate R&D expenditures in Belgium (2001-2009), *Reflets et perspectives de la vie économique*, no. 1, pp. 69-91.

Duso T., Roller L.H. and Seldeslachts J, 2014, Collusion through joint R&D:An empirical assessment, *The Review of Economics and Statistics*, no. 96(2), pp. 349-370.

Ernst, C., K. Richter and N. Riedel, 2014, Corporate taxation and the quality of research and development, *International Tax and Public Finance*, pp. 1-26.

Ernst, C. and C. Spengel, 2011, Taxation, R&D tax incentives and patent application in Europe, ZEW Discussion Papers 11-024.

European Commission, 2007, Towards a more effective use of tax incentives in favour of R&D, COM(2006)728.

European Commission, 2008, Comparing Practices in R&D Tax Incentives Evaluation. Final Report of the Expert Group on R&D Tax Incentives Evaluation, Brussels.

European Commission, 2014, *Innovation Union Scoreboard 2014,* European Union, Belgium.

Evers, L., H. Miller and C. Spengel, 2014, Intellectual property box regimes: Effective tax rates and tax policy considerations, *International Tax and Public Finance*.

Gaillard-Ladinska, E., M. Non and B. Straathof, 2014, More R&D with tax incentives? A meta-analysis, CPB Discussion Paper.

Garcia-Quevedo, J., 2004, Do public subsidies complement business R&D? A meta-analysis of the econometric evidence, *Kyklos*, vol. 57, pp. 87-102.

Ghosh, M., 2007, R&D Policies and Endogenous Growth: A Dynamic General Equilibrium Analysis of the Case for Canada*, *Review of Development Economics*, vol. 11, no. 1, pp. 187-203.

Goolsbee, A., 1998, Does government R&D policy mainly benefit scientists and engineers?, *American Economic Review*, vol. 88, no. 2, pp. 298-302.

Griffith, R., H. Miller and M. O'Connell, 2014, Ownership of intellectual property and corporate taxation, *Journal of Public Economics*, vol. 112, pp. 12-23.

Grubert, H., 2003, Intangible income, intercompany transactions, income shifting, and the choice of location, *National Tax Journal*, pp. 221-242.

Grubert, H. and J. Slemrod, 1998, The effect of taxes on investment and income shifting to Puerto Rico, *Review of Economics and Statistics*, vol. 80, no. 3, pp. 365-373.

Hægeland, T. and J. Møen, 2007a, Input additionality in the Norwegian R&D tax credit scheme, Reports 2007/47 Statistics Norway.

Hægeland, T. and J. Møen, 2007b, The relationship between the Norwegian R&D tax credit scheme and other innovation policy instruments, *Statistics Norway*.

Hall, B. and J. Van Reenen, 2000, How effective are fiscal incentives for R&D? A review of the evidence, *Research Policy*, vol. 29, no. 4, pp. 449-469.

Hall, B.H., Z. Griliches and J.A. Hausman, 1986, Patents and R&D: Is there a lag?, NBER Working Paper 1454.

Hall, B.H., J. Mairesse and P. Mohnen, 2009, Measuring the Returns to R&D, NBER Working Paper Series.

Hallépée S. and A.H. Garcia, 2012, Évaluation du dispositif JEI, DGCIS/Ministère du Redressement Productif, Paris, France.

Harhoff, D., F. Narin, F.M. Scherer and K. Vopel, 1999, Citation frequency and the value of patented inventions, *Review of Economics and Statistics*, vol. 81, no. 3, pp. 511-515.

Harris, R., Q.C. Li and M. Trainor, 2009, Is a higher rate of R&D tax credit a panacea for low levels of R&D in disadvantaged regions?, *Research Policy*, vol. 38, no. 1, pp. 192-205.

Hart, O., A. Shleifer and R.W. Vishny, 1997, The Proper Scope of Government: Theory and an Application to Prisons, *The Quarterly Journal of Economics*, vol. 112, no. 4, pp. 1127-1161.

HMRC, 2010, An Evaluation of Research and Development Tax Credits, HMRC Research Report 107.

Ho, Y., 2006, Evaluating the effectiveness of state R&D tax credits, University of Pittsburgh.

Ientile, D. and J. Mairesse, 2009, A policy to boost R&D: Does the R&D tax credit work?, *EIB papers*, vol. 14, no. 1, pp. 144-169.

Karkinsky, T. and N. Riedel, 2012, Corporate taxation and the choice of patent location within multinational firms, *Journal of International Economics*, vol. 88, no. 1, pp. 176-185.

Kasahara, H., K. Shimotsu and M. Suzuki, 2013, Does an R&D tax credit affect R&D expenditure? The Japanese R&D tax credit reform in 2003, *Journal of the Japanese and International Economies*.

Klassen, K.J., J.A. Pittman, M.P. Reed and S.T.E.V. Fortin, 2004, A Cross–national Comparison of R&D Expenditure Decisions: Tax Incentives and Financial Constraints, *Contemporary Accounting Research*, vol. 21, no. 3, pp. 639-680.

Koga, T., 2003, Firm size and R&D tax incentives, *Technovation*, vol. 23, no. 7, pp. 643-648.

Köhler, C., P. Laredo and C. Rammer, 2012, The Impact and Effectiveness of Fiscal Incentives for R&D, *Compendium of Evidence on the effectiveness of Innovation Policy*.

Lach, S. and M. Schankerman, 1989, Dynamics of R&D and Investment in the Scientific Sector, *Journal of Political Economy*, vol. 97, no. 4, pp. 880-904.

Lee, C.Y., 2011, The differential effects of public R&D support on firm R&D: Theory and evidence from multi-country data, *Technovation*, vol. 31, no. 5, pp. 256-269.

Lester, J. and J. Warda, 2014, An International Comparison of Tax Assistance for Research and Development:Estimates and Policy Implications, Working Paper.

Lhuillery, S., M. Marino and P. Parrotta, 2013, Evaluation de l'impact des aides directes et indirectes à la R&D en France, Rapport pour le Ministère de l'enseignement supérieur et de la recherche.

Lokshin, B. and P. Mohnen, 2012, How effective are level-based R&D tax credits? Evidence from the Netherlands, *Applied Economics*, vol. 44, no. 12, pp. 1527-1538.

Lokshin, B. and P. Mohnen, 2013, Do R&D tax incentives lead to higher wages for R&D workers? Evidence from the Netherlands, *Research Policy*, vol. 42, no. 3, pp. 823-830.

Mohnen, P. and B. Lokshin, 2008, What drives the dynamics of business growth?, *Reforming Rules and Regulations*, pp. 33-58.

Mohnen, P. and B. Lokshin, 2011, What does it take for an R&D tax incentive policy to be effective?, in V. Ghosal eds., *Reforming Rules and Regulations*.

Mulkay, B. and J. Mairesse, 2003, The effect of the R&D tax credit in France, EEA-ESEM Conference, pp. 20-24.

Mulkay, B. and J. Mairesse, 2008, Financing R&D Through Tax Credit in France, *LEREPS and UNU-MERIT Preliminary Draft*.

Mulkay, B. and J. Mairesse, 2013, The R&D tax credit in France: assessment and ex ante evaluation of the 2008 reform, *Oxford Economic Papers*, vol. 65, no. 3, pp. 746-766.

Mutti, J. and H. Grubert, 2009, The effect of taxes on royalties and the migration of intangible assets abroad, *International trade in services and intangibles in the era of globalization,* University of Chicago Press.

Nooteboom, B. and E. Stam, 2008, *Micro-foundations for innovation policy,* Amsterdam University Press.

OECD, 2002, *Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development,* OECD, Paris.

OECD, 2011, *The International Experience with R&D Tax Incentives. Testimony for the United States Senate Committee on Finance,* OECD Publishing, Paris.

OECD, 2013a, *Action Plan on Base Erosion and Profit Shifting,* OECD Publishing, Paris.

OECD, 2013b, *Supporting Investment in Knowledge Capital, Growth and Innovation,* OECD, Paris.

Parisi, M.L. and A. Sembenelli, 2001, Is Private R&D Spending Sensitive to Its Price? Empirical Evidence on Panel Data for Italy.

Parsons, M. and N. Phillips, 2007, An evaluation of the federal tax credit for scientific research and experimental development, Department of Finance, Economic and Fiscal Policy Branch.

Poot, T., P. den Hertog, T. Grosfeld and E. Brouwer, 2003, Evaluation of a major Dutch Tax Credit Scheme (WBSO) aimed at promoting R&D, FTEVAL Conference on the Evaluation of Government Funded R&D, Vienna.

Rao, N., 2013, Do Tax Credits Stimulate R&D Spending? The Effect of the R&D Tax Credit in its First Decade, NYU Wagner Research Paper 2272174.

Romer, P.M., 1990, Endogenous Technological Change, *Journal of Political Economy*, vol. 98, no. 5, pp. S71-S102.

Russo, B., 2004, A cost–benefit analysis of R&D tax incentives, *Canadian Journal of Economics/Revue canadienne d'economique*, vol. 37, no. 2, pp. 313-335.

Scherer, F.M. and D. Harhoff, 2000, Technology policy for a world of skew-distributed outcomes, *Research Policy*, vol. 29, no. 4, pp. 559-566.

Stanley, T.D., 2008, Meta Regression Methods for Detecting and Estimating Empirical Effects in the Presence of Publication Selection*, *Oxford Bulletin of Economics and Statistics*, vol. 70, no. 1, pp. 103-127.

Stöwhase, S., 2002, Profit Shifting opportunities, Multinationals, and the determinants of FDI, *Munich Discussion Paper No.2002-11*.

Streicher, G., A. Schibany and N. Gretzmacher, 2004, Input additionality effects of R&D subsidies in Austria, *Empirical Evidence from Firm-level Panel Data*, pp. 9-11.

Takalo, T., T. Tanayama and O. Toivanen, 2013, Estimating the benefits of targeted R&D subsidies, *Review of Economics and Statistics*, vol. 95, no. 1, pp. 255-272.

Verhoeven, W.H.J., A.J. Van Stel and N.G.L. Timmermans, 2012, Evaluatie WBSO 2006-2010, Ministerie van Economische Zaken.

Warda, J., 2001, Measuring the Value of R&D Tax Treatment in OECD Countries, *STI Review*, vol. 27.

Westmore, B., 2013, R&D, Patenting and Growth: The Role of Public Policy, OECD Economics Department Working Papers 1047.

Wilson, D.J., 2009, Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits, *The Review of Economics and Statistics*, vol. 91, no. 2, pp. 431-436.

Yohei, K.O.B.A., 2011, Effect of R&D Tax Credits for Small and Medium-sized Enterprises in Japan: Evidence from firm-level data, RIETI Discussion Paper Series 11-E-066.

Zuniga-Vicente, J., C. Alonso-Borrego, F.J. Forcadell and J.I. Galan, 2012, Assessing the effect of public subsidies on firm R&D investment: a survey, *Journal of Economic Surveys*, vol. 28, no. 1, pp. 36-67.

Annex 1. Methodology

Hierarchical Clustering

The country/features matrix is an incidence matrix (also called a biadjacency matrix of a bipartite graph) that shows which instrument features (the columns) are present in which countries (the rows). The entry in row i, column j is 1 when the country i has an R&D tax incentive instrument for a particular scope, targeting or organization feature j, and 0 otherwise.

The objects that are to be clustered are countries represented by the 30 rows of the matrix. The distance between each pair of countries was calculated using the Jaccard similarity coefficient as the metric. More precisely, the Jaccard distance (= 1 - Jaccard coefficient) measures the dissimilarity between objects; it is defined as the fraction (or percentage) of nonzero coordinates that differ from each other. Thus the Jaccard distance between two country row vectors r_A and r_B is given by

$$d_{Jacc}(r_A, r_B) = \frac{sum[abs(r_A - r_B)]}{sum[\max(r_A, r_B)]},$$

where abs and $\max$ are row vectors of absolute and maximum values respectively, and sum is the row sum.

For example, the Jaccard distance for the rows representing Portugal and the United States = 4/14 = 0.2857. This is in fact the lowest distance between any two countries in the sample, and corresponds to the "lowest" branch (or leaf) of the dendrogram. The pairs of countries separated by the next lowest distances are likewise identified. The distance of a country (or countries in a leaf/branch) from another already formed leaf/branch is the average distance from each of the branch's members. When the next least great distance is found to be between a country and other countries already identified as being in a branch then this tree branch is 'grown' by inclusion of the 'new' country or countries. (see the dendrogram Figure 5.11), Japan is joined with Portugal and the United States, Italy with the pair Spain and Ireland, then these two branches are joined to form a larger branch). The tree structure is thus increased agglomeratively from bottom to top until all countries are linked by branches of one tree i.e. dendrogram.

In a further step the visual display of the dendrogram assists in identifying useful clusters that are chosen as a result of balancing the internal distances of cluster members and distances between separate clusters. The result is a judgement based on the quantitative information contained in the 'height' at which new clusters are 'grown' or 'pruned'. In the analysis here, colours are used to distinguish the different clusters identified in the course of 'tree cutting'.

Robustness of benchmarking results to choice of weights

The formula used to compute the overall score of an instrument is given by:

$$t_i = \frac{1}{4}\left(\frac{s_i}{\bar{s}} + \frac{t_i}{\bar{t}} + \frac{2o_i}{\bar{o}}\right)\left(\frac{\bar{s} + \bar{t} + 2\bar{o}}{4}\right)$$

Here, t_i is the overall score of instrument i, and s, t, o are the scores on scope, targeting, and organization. Variables with a bar are mean values over instruments. The two primary features of this formula are 1) the correction for differences in means between the categories scope, targeting and organization and 2) the double weight for organization.

In order to assess the impact of these features on the ranking of instruments, we have computed two alternative scores, one with uniform weights for all three categories,

$$t_i = \frac{1}{3}\left(\frac{s_i}{\bar{s}} + \frac{t_i}{\bar{t}} + \frac{o_i}{\bar{o}}\right)\left(\frac{\bar{s} + \bar{t} + \bar{o}}{3}\right)$$

and one without corrections for differences in means,

$$t_i = \frac{s_i + t_i + 2o_i}{4}.$$

The table below shows the spearman rank-correlations for the three types of scores. The correlation coefficients range from 0.96 to 0.99, which suggests that the three formula's lead to highly similar rankings.

Spearman rank correlations for alternative weighting formula's

	Baseline	Uniform weights	No mean correction
Baseline	1.00		
Uniform weights	0.96	1.00	
No mean correction	0.98	0.99	1.00

In the second table the baseline top ten of instruments is displayed together with their ranking under alternative weighting choices. No instrument in the baseline top ten reaches a position below fifteen under alternative weighting choices. The top ten of instruments varies with the choices made for weighting, but this variation is not very large.

Robustness of top ten instruments to weighting choices

Instrument	Country	Baseline	Uniform weights	No mean correction
Jeunes Entreprises Innovantes	FR	1	1	1
SkatteFUNN	NO	2	3	2
Accelerated amortization	DK	3	14	6
SR&ED	CA	4	2	3
WBSO	NL	5	4	4
R&D Tax Credit	IE	6	10	7
Capital Investments	IL	7	11	10
R&D Relief	UK	8	7	8
Skattekreditordningen	DK	9	15	14
R&D tax allowance	IL	9	15	14

Annex 2. Detailed scores on scope

Country	Instrument	Tax incentive*	Tax credits vs. enh. allowances	Input vs. output	Volume-based vs. incremental	Expenditure covered	Novelty requirement	Scope total
AT	Forschungsprämie	TC	1.0	1.0	1.0	0.0	-1.0	0.4
BE	In-house R&D inv. deduction	AD	0.0	1.0	1.0	0.0	1.0	0.6
BE	In-house R&D inv. deduction	TC	1.0	1.0	1.0	0.0	1.0	0.8
BE	Patent Income Deduction	PB	-1.0	-1.0	1.0	-1.0	1.0	-0.2
BE	Payroll tax deduction for R&D	TC	1.0	1.0	1.0	1.0	-1.0	0.6
BG	Accelerated tax depreciation	AD	0.0	1.0	1.0	0.0	0.0	0.4
BG	R&D expenditure write-off	AD	0.0	-1.0	1.0	-1.0	0.0	-0.2
BG	Remission of the CIT	TC	1.0	-1.0	1.0	-1.0	0.0	0.0
CA	Provincial R&D tax incentives	TC	1.0	1.0	1.0	0.1	1.0	0.8
CA	SR&ED	AD	0.0	1.0	1.0	0.0	1.0	0.6
CA	SR&ED	TC	1.0	1.0	1.0	0.0	1.0	0.8
CY	Enhanced allowance	EA	0.0	-1.0	1.0	-1.0	-1.0	-0.4
CY	Patent box	PB	-1.0	-1.0	1.0	-1.0	-1.0	-0.6
CZ	R&D centers CIT relief	RR	0.0	-1.0	1.0	-1.0	-1.0	-0.4
CZ	R&D super deduction	EA	0.0	1.0	-1.0	0.0	0.0	0.0
DK	Accelerated amortization	AD	0.0	0.0	1.0	-0.5	-1.0	-0.1
DK	Skattekreditordningen	TC	1.0	1.0	1.0	0.0	-1.0	0.4
EL	Enhanced allowance for R&D	EA	0.0	1.0	1.0	0.0	0.0	0.4
EL	Outcome incentive	PB	-1.0	-1.0	1.0	-1.0	0.0	-0.4
ES	Credit for R&D personnel	TC	1.0	1.0	1.0	1.0	-1.0	0.6
ES	Incremental credit	TC	1.0	1.0	-1.0	0.0	0.0	0.2
ES	Innovation Tax Credit	TC	1.0	-1.0	1.0	0.0	0.0	0.2
ES	Patent box	PB	-1.0	-1.0	1.0	-1.0	0.0	-0.4
ES	R&D equipment credit	TC	1.0	-1.0	1.0	0.0	0.0	0.2
ES	Volume credit	TC	1.0	1.0	1.0	0.0	-1.0	0.4
FI	Accelerated depreciation	AD	0.0	1.0	1.0	0.0	-1.0	0.2
FI	Deduction for R&D wages	EA	0.0	1.0	1.0	1.0	-1.0	0.4
FR	Crédit d'Impôt Innovation	TC	1.0	1.0	1.0	0.0	1.0	0.8
FR	Crédit d'Impôt Recherche	TC	1.0	1.0	1.0	0.0	1.0	0.8
FR	Jeunes Entreprises Innovantes	TC	1.0	1.0	1.0	1.0	1.0	1.0
FR	Patent box	PB	-1.0	-1.0	0.0	-1.0	1.0	-0.4
HR	Enhanced allowance for R&D	EA	0.0	1.0	1.0	0.0	0.0	0.4
HR	Technical feasibility	EA	0.0	1.0	1.0	0.0	0.0	0.4
HU	Enhanced allowance	EA	0.0	1.0	1.0	0.0	0.0	0.4
HU	Patent Box	PB	-1.0	-1.0	1.0	-1.0	0.0	-0.4
HU	Reduced soc. sec. contrib.	HY	0.0	1.0	1.0	1.0	0.0	0.6

Country	Instrument	Tax incentive*	Tax credits vs. enh. allowances	Input vs. output	Volume-based vs. incremental	Expenditure covered	Novelty requirement	Scope total
HU	Wages Tax Allowance	EA	0.0	1.0	1.0	1.0	0.0	0.6
IE	R&D Tax Credit	TC	1.0	1.0	0.3	0.0	-1.0	0.3
IL	Capital Investments	AD	0.0	1.0	1.0	0.0	0.0	0.4
IL	Priority Areas	RR	0.0	-1.0	1.0	-1.0	0.0	-0.2
IL	R&D tax allowance	EA	0.0	1.0	1.0	0.0	0.0	0.4
IT	Accelerated depreciation	AD	0.0	1.0	1.0	0.0	0.0	0.4
IT	Decreto Destinazione Italia	TC	1.0	1.0	-1.0	1.0	1.0	0.6
IT	Tax credit researchers	TC	1.0	1.0	1.0	0.0	0.0	0.6
JP	ABLL	EA	0.0	1.0	1.0	0.0	1.0	0.6
JP	CSZL	AD	0.0	1.0	1.0	0.0	-1.0	0.2
JP	CSZL	EA	0.0	1.0	1.0	0.0	-1.0	0.2
JP	CSZL	TC	1.0	1.0	1.0	0.0	-1.0	0.4
JP	General tax credit system	TC	1.0	1.0	0.5	0.0	-1.0	0.3
JP	R&D tax incentives for SMEs	TC	1.0	1.0	1.0	0.0	-1.0	0.4
LT	300% super deduction	EA	0.0	1.0	1.0	0.0	1.0	0.6
LT	Accelerated depreciation	AD	0.0	1.0	1.0	0.0	1.0	0.6
LU	Tax exemption IP income	PB	-1.0	-1.0	1.0	-1.0	1.0	-0.2
LV	Enhanced allowance	EA	0.0	1.0	1.0	1.0	-1.0	0.4
MT	R&D tax credit	TC	1.0	0.0	1.0	-0.5	-1.0	0.1
MT	Royalty Income from Patents	PB	-1.0	-1.0	1.0	-1.0	-1.0	-0.6
NL	Innovatiebox	PB	-1.0	-1.0	1.0	-1.0	1.0	-0.2
NL	RDA	EA	0.0	1.0	1.0	0.0	-1.0	0.2
NL	WBSO	TC	1.0	1.0	1.0	1.0	-1.0	0.6
NO	SkatteFUNN	TC	1.0	1.0	1.0	0.0	-1.0	0.4
PL	New Tax Relief	HY	0.0	1.0	1.0	0.0	1.0	0.6
PL	New Technology Tax Relief	EA	0.0	-1.0	1.0	0.0	1.0	0.2
PL	Tax Deduction R&D Centers	EA	0.0	-1.0	1.0	0.0	-1.0	-0.2
PL	Tax Exemption R&D Centers	RR	0.0	-1.0	1.0	0.0	-1.0	-0.2
PL	Tax Exemption SEZ	RR	0.0	0.0	1.0	0.0	-1.0	0.0
PT	Patent box	PB	-1.0	-1.0	1.0	-1.0	1.0	-0.2
PT	SIFIDE II	TC	1.0	1.0	0.0	0.0	1.0	0.6
RO	Accelerated depreciation	AD	0.0	1.0	1.0	0.0	0.0	0.4
RO	Super deduction	EA	0.0	1.0	1.0	0.0	1.0	0.6
SE	Reduced soc. sec. contrib.	TC	1.0	1.0	1.0	1.0	0.0	0.8
SI	Allowance for investment	EA	0.0	1.0	1.0	0.0	0.0	0.4
SI	Depreciation allowance	AD	0.0	1.0	1.0	0.0	0.0	0.4
SI	R&D tax relief	EA	0.0	1.0	1.0	0.0	0.0	0.4

Country	Instrument	Tax incentive*	Tax credits vs. enh. allowances	Input vs. output	Volume-based vs. incremental	Expenditure covered	Novelty requirement	Scope total
SK	R&D Tax credit	TC	1.0	1.0	1.0	0.0	-1.0	0.4
UK	R&D Allowance	AD	0.0	1.0	1.0	0.0	1.0	0.6
UK	R&D Relief	EA	0.0	1.0	1.0	0.0	1.0	0.6
UK	R&D Relief	TC	1.0	1.0	1.0	0.0	1.0	0.8
UK	The Patent Box	PB	-1.0	-1.0	1.0	-1.0	1.0	-0.2
US	Credit for Incr. Res. Act.	TC	1.0	1.0	-1.0	0.0	-1.0	0.0
US	Orphan drug research credit	TC	1.0	1.0	1.0	0.0	-1.0	0.4
US	Section 174 tax deduction	AD	0.0	1.0	1.0	0.0	-1.0	0.2
US	Special tax credit schedules	TC	1.0	1.0	0.0	0.0	-1.0	0.2
US	State R&D tax incentives	TC	1.0	1.0	-0.3	0.0	-1.0	0.1

* AD = accelerated depreciation; EA = enhanced allowance; HY = hybrid; PB = patent box; RR = reduced tax rate; TC = tax credit

Annex 3. Detailed scores on targeting

Country	Instrument	Tax incentive*	Region	Legal form	Firm size	Field of activity	Firm age	Minimum	Brackets	Negative tax	Carry-over	Targeting total
AT	Forschungsprämie	TC	1.0	0.0	1.0	1.0	0.0	1.0	0.5	-1.0	-1.0	0.3
BE	In-house R&D inv. deduction	AD	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	-1.0	0.7
BE	In-house R&D inv. deduction	TC	1.0	1.0	1.0	-1.0	0.0	1.0	1.0	1.0	1.0	0.7
BE	Patent Income Deduction	PB	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
BE	Payroll tax deduction for R&D	TC	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.9
BG	Accelerated tax depreciation	AD	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
BG	R&D expenditure write-off	AD	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	0.7
BG	Remission of the CIT	TC	1.0	-1.0	1.0	-1.0	0.0	1.0	1.0	0.0	0.0	0.2
CA	Provincial R&D tax incentives	TC	-1.0	0.8	1.0	0.9	0.0	1.0	0.8	0.8	0.5	0.5
CA	SR&ED	AD	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.8
CA	SR&ED	TC	1.0	-1.0	1.0	1.0	0.0	1.0	0.3	0.3	0.5	0.4
CY	Enhanced allowance	EA	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	0.0	0.4
CY	Patent box	PB	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	0.0	0.4
CZ	R&D centers CIT relief	RR	1.0	-1.0	1.0	1.0	0.0	0.0	1.0	-1.0	1.0	0.3
CZ	R&D super deduction	EA	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	1.0	0.6
DK	Accelerated amortization	AD	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.8
DK	Skattekreditordningen	TC	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	-1.0	0.4
EL	Enhanced allowance for R&D	EA	-1.0	1.0	0.0	1.0	1.0	1.0	0.0	-1.0	1.0	0.3
EL	Outcome incentive	PB	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	-1.0	0.4
ES	Credit for R&D personnel	TC	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.9
ES	Incremental credit	TC	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0	0.8
ES	Innovation Tax Credit	TC	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	0.7
ES	Patent box	PB	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.8
ES	R&D equipment credit	TC	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.9
ES	Volume credit	TC	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.8
FI	Accelerated depreciation	AD	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	1.0	0.6
FI	Deduction for R&D wages	EA	1.0	-1.0	1.0	1.0	0.0	-1.0	0.0	-1.0	1.0	0.1
FR	Crédit d'Impôt Innovation	TC	1.0	1.0	0.0	1.0	0.0	1.0	0.0	-1.0	1.0	0.4
FR	Crédit d'Impôt Recherche	TC	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.8
FR	Jeunes Entreprises Innovantes	TC	1.0	1.0	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.7
FR	Patent box	PB	1.0	1.0	0.0	1.0	-1.0	1.0	0.0	-1.0	-1.0	0.1
HR	Enhanced allowance for R&D	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.8
HR	Technical feasibility	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.9
HU	Enhanced allowance	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
HU	Patent Box	PB	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
HU	Reduced soc. sec. contrib.	HY	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.8

Country	Instrument	Tax incentive*	Region	Legal form	Firm size	Field of activity	Firm age	Minimum	Brackets	Negative tax	Carry-over	Targeting total
HU	Wages Tax Allowance	EA	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0	1.0	0.7
IE	R&D Tax Credit	TC	1.0	1.0	1.0	1.0	0.0	0.7	0.7	0.7	1.0	0.8
IL	Capital Investments	AD	1.0	1.0	1.0	-1.0	1.0	1.0	0.0	0.0	1.0	0.6
IL	Priority Areas	RR	-1.0	1.0	1.0	-1.0	0.0	1.0	1.0	0.0	0.0	0.2
IL	R&D tax allowance	EA	1.0	1.0	1.0	-1.0	0.0	1.0	1.0	0.0	0.0	0.4
IT	Accelerated depreciation	AD	1.0	1.0	1.0	1.0	1.0	-1.0	0.0	0.0	0.0	0.7
IT	Decreto Destinazione Italia	TC	1.0	1.0	1.0	1.0	0.0	-1.0	0.0	-1.0	0.0	0.2
IT	Tax credit researchers	TC	1.0	1.0	0.0	1.0	0.0	-1.0	0.0	1.0	0.0	0.3
JP	ABLL	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.7
JP	CSZL	AD	1.0	1.0	1.0	1.0	0.0	-1.0	1.0	-1.0	1.0	0.4
JP	CSZL	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.7
JP	CSZL	TC	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.7
JP	General tax credit system	TC	1.0	1.0	-0.3	1.0	0.0	0.8	1.0	-1.0	1.0	0.5
JP	R&D tax incentives for SMEs	TC	1.0	1.0	0.0	1.0	0.0	0.0	1.0	-1.0	1.0	0.4
LT	300% super deduction	EA	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	-1.0	0.3
LT	Accelerated depreciation	AD	1.0	1.0	1.0	1.0	0.0	0.0	0.0	-1.0	1.0	0.4
LU	Tax exemption IP income	PB	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
LV	Enhanced allowance	EA	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	1.0	0.6
MT	R&D tax credit	TC	1.0	-1.0	0.0	1.0	0.0	1.0	0.0	-1.0	1.0	0.2
MT	Royalty Income from Patents	PB	1.0	-1.0	1.0	1.0	0.0	1.0	0.0	-1.0	0.0	0.2
NL	Innovatiebox	PB	1.0	1.0	1.0	1.0	0.0	0.0	-1.0	-1.0	1.0	0.3
NL	RDA	EA	1.0	0.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.6
NL	WBSO	TC	1.0	0.0	1.0	1.0	0.5	0.0	0.0	1.0	0.0	0.5
NO	SkatteFUNN	TC	1.0	1.0	0.0	1.0	0.0	1.0	0.0	0.5	-1.0	0.4
PL	New Tax Relief	HY	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.7
PL	New Technology Tax Relief	EA	0.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	1.0	0.6
PL	Tax Deduction R&D Centers	EA	1.0	-1.0	1.0	1.0	0.0	1.0	1.0	-1.0	-1.0	0.2
PL	Tax Exemption R&D Centers	RR	1.0	-1.0	1.0	1.0	0.0	1.0	0.0	-1.0	1.0	0.3
PL	Tax Exemption SEZ	RR	1.0	1.0	-0.3	1.0	0.0	-1.0	1.0	-1.0	1.0	0.3
PT	Patent box	PB	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.8
PT	SIFIDE II	TC	1.0	1.0	0.8	1.0	0.2	1.0	0.6	-1.0	1.0	0.6
RO	Accelerated depreciation	AD	1.0	0.0	1.0	1.0	0.0	0.0	1.0	-1.0	0.0	0.3
RO	Super deduction	EA	1.0	0.0	1.0	1.0	0.0	0.0	1.0	-1.0	0.0	0.3
SE	Reduced soc. sec. contrib.	TC	1.0	-1.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.6
SI	Allowance for investment	EA	1.0	-1.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.6
SI	Depreciation allowance	AD	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7
SI	R&D tax relief	EA	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.8
SK	R&D Tax credit	TC	1.0	1.0	1.0	1.0	0.0	0.0	1.0	-1.0	-1.0	0.3

Country	Instrument	Tax incentive*	Region	Legal form	Firm size	Field of activity	Firm age	Minimum	Brackets	Negative tax	Carry-over	Targeting total
UK	R&D Allowance	AD	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	0.0	0.6
UK	R&D Relief	EA	1.0	1.0	-0.5	1.0	0.0	1.0	1.0	0.0	1.0	0.6
UK	R&D Relief	TC	1.0	1.0	-1.0	1.0	0.0	1.0	1.0	0.0	1.0	0.6
UK	The Patent Box	PB	1.0	1.0	1.0	1.0	0.0	1.0	1.0	-1.0	0.0	0.6
US	Credit for Incr. Res. Act.	TC	1.0	1.0	0.8	1.0	0.3	0.0	1.0	0.0	1.0	0.7
US	Orphan drug research credit	TC	1.0	1.0	1.0	-1.0	0.0	0.0	1.0	0.0	0.0	0.3
US	Section 174 tax deduction	AD	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	0.7
US	Special tax credit schedules	TC	1.0	1.0	1.0	-1.0	0.0	0.0	1.0	0.0	0.0	0.3
US	State R&D tax incentives	TC	-1.0	1.0	1.0	1.0	0.1	0.3	0.8	0.0	0.8	0.4

* AD = accelerated depreciation; EA = enhanced allowance; HY = hybrid; PB = patent box; RR = reduced tax rate; TC = tax credit

Annex 4. Detailed scores on organization

Country	Instrument	Tax incentive*	Decision time	Electronic application	One-stop application	Public consultation	Evaluation	Organization total
AT	Forschungsprämie	TC	0.0	1.0	1.0	0.0	-1.0	0.2
BE	In-house R&D inv. deduction	AD	-1.0	1.0	-1.0	0.0	0.0	-0.2
BE	In-house R&D inv. deduction	TC	-1.0	1.0	-1.0	0.0	0.0	-0.2
BE	Patent Income Deduction	PB	0.0	-1.0	1.0	0.0	0.0	0.0
BE	Payroll tax deduction for R&D	TC	1.0	0.0	-1.0	0.0	1.0	0.2
BG	Accelerated tax depreciation	AD	0.0	0.0	0.0	0.0	0.0	0.0
BG	R&D expenditure write-off	AD	0.0	0.0	0.0	0.0	0.0	0.0
BG	Remission of the CIT	TC	0.0	0.0	0.0	0.0	0.0	0.0
CA	Provincial R&D tax incentives	TC	0.6	1.0	0.3	0.0	0.0	0.4
CA	SR&ED	AD	0.0	1.0	1.0	1.0	-1.0	0.4
CA	SR&ED	TC	0.8	1.0	1.0	1.0	-1.0	0.6
CY	Enhanced allowance	EA	0.0	0.0	0.0	0.0	0.0	0.0
CY	Patent box	PB	0.0	0.0	0.0	0.0	0.0	0.0
CZ	R&D centers CIT relief	RR	1.0	1.0	1.0	0.0	0.0	0.6
CZ	R&D super deduction	EA	1.0	1.0	1.0	0.0	0.0	0.6
DK	Accelerated amortization	AD	1.0	1.0	1.0	0.0	1.0	0.8
DK	Skattekreditordningen	TC	-1.0	1.0	1.0	1.0	1.0	0.6
EL	Enhanced allowance for R&D	EA	1.0	1.0	-1.0	-1.0	0.0	0.0
EL	Outcome incentive	PB	0.0	0.0	0.0	-1.0	0.0	-0.2
ES	Credit for R&D personnel	TC	0.0	1.0	1.0	0.0	0.0	0.4
ES	Incremental credit	TC	0.0	1.0	1.0	0.0	0.0	0.4
ES	Innovation Tax Credit	TC	0.0	1.0	1.0	0.0	0.0	0.4
ES	Patent box	PB	0.0	1.0	1.0	0.0	0.0	0.4
ES	R&D equipment credit	TC	0.0	1.0	1.0	0.0	0.0	0.4
ES	Volume credit	TC	0.0	1.0	1.0	0.0	0.0	0.4
FI	Accelerated depreciation	AD	-1.0	1.0	1.0	-1.0	-1.0	-0.2
FI	Deduction for R&D wages	EA	-1.0	1.0	1.0	1.0	1.0	0.6
FR	Crédit d'Impôt Innovation	TC	1.0	-1.0	-1.0	-1.0	0.0	-0.4
FR	Crédit d'Impôt Recherche	TC	1.0	1.0	-1.0	0.0	0.0	0.2
FR	Jeunes Entreprises Innovantes	TC	1.0	-1.0	1.0	1.0	1.0	0.6
FR	Patent box	PB	0.0	-1.0	1.0	1.0	1.0	0.4
HR	Enhanced allowance for R&D	EA	1.0	-1.0	-1.0	0.0	0.0	-0.2
HR	Technical feasibility	EA	1.0	-1.0	-1.0	0.0	0.0	-0.2
HU	Enhanced allowance	EA	0.0	0.0	0.0	0.0	0.0	0.0
HU	Patent Box	PB	0.0	0.0	0.0	0.0	0.0	0.0
HU	Reduced soc. sec. contrib.	HY	0.0	0.0	0.0	0.0	0.0	0.0

Country	Instrument	Tax incentive*	Decision time	Electronic application	One-stop application	Public consultation	Evaluation	Organization total
HU	Wages Tax Allowance	EA	0.0	0.0	0.0	0.0	0.0	0.0
IE	R&D Tax Credit	TC	0.0	1.0	1.0	1.0	0.0	0.6
IL	Capital Investments	AD	1.0	1.0	1.0	0.0	0.0	0.6
IL	Priority Areas	RR	1.0	1.0	1.0	0.0	0.0	0.6
IL	R&D tax allowance	EA	1.0	1.0	1.0	0.0	0.0	0.6
IT	Accelerated depreciation	AD	0.0	1.0	1.0	0.0	-1.0	0.3
IT	Decreto Destinazione Italia	TC	0.0	1.0	1.0	1.0	-1.0	0.4
IT	Tax credit researchers	TC	0.0	1.0	1.0	-1.0	-1.0	0.0
JP	ABLL	EA	0.0	0.0	1.0	0.0	0.0	0.2
JP	CSZL	AD	0.0	0.0	1.0	0.0	0.0	0.2
JP	CSZL	EA	0.0	0.0	1.0	0.0	0.0	0.2
JP	CSZL	TC	0.0	0.0	1.0	0.0	0.0	0.2
JP	General tax credit system	TC	0.0	0.0	1.0	0.0	0.0	0.2
JP	R&D tax incentives for SMEs	TC	0.0	0.0	1.0	0.0	0.0	0.2
LT	300% super deduction	EA	0.0	0.0	0.0	0.0	0.0	0.0
LT	Accelerated depreciation	AD	0.0	0.0	0.0	0.0	0.0	0.0
LU	Tax exemption IP income	PB	0.0	0.0	0.0	0.0	0.0	0.0
LV	Enhanced allowance	EA	0.0	1.0	1.0	-1.0	-1.0	0.0
MT	R&D tax credit	TC	0.0	-1.0	1.0	-1.0	-1.0	-0.4
MT	Royalty Income from Patents	PB	0.0	-1.0	1.0	-1.0	-1.0	-0.4
NL	Innovatiebox	PB	0.0	0.0	1.0	0.0	1.0	0.4
NL	RDA	EA	1.0	1.0	1.0	-1.0	1.0	0.6
NL	WBSO	TC	1.0	1.0	1.0	-1.0	1.0	0.6
NO	SkatteFUNN	TC	1.0	1.0	1.0	0.0	1.0	0.8
PL	New Tax Relief	HY	1.0	0.0	1.0	1.0	-1.0	0.4
PL	New Technology Tax Relief	EA	1.0	0.0	1.0	-1.0	-1.0	0.0
PL	Tax Deduction R&D Centers	EA	1.0	-1.0	1.0	-1.0	-1.0	-0.2
PL	Tax Exemption R&D Centers	RR	1.0	-1.0	1.0	-1.0	-1.0	-0.2
PL	Tax Exemption SEZ	RR	0.3	-1.0	1.0	-1.0	-0.3	-0.2
PT	Patent box	PB	0.0	1.0	1.0	-1.0	0.0	0.2
PT	SIFIDE II	TC	0.0	1.0	1.0	-1.0	0.0	0.2
RO	Accelerated depreciation	AD	0.0	-1.0	0.0	-1.0	0.0	-0.4
RO	Super deduction	EA	1.0	-1.0	-1.0	1.0	1.0	0.2
SE	Reduced soc. sec. contrib.	TC	1.0	1.0	1.0	-1.0	-1.0	0.2
SI	Allowance for investment	EA	0.0	1.0	1.0	0.0	0.0	0.4
SI	Depreciation allowance	AD	0.0	0.0	0.0	0.0	0.0	0.0
SI	R&D tax relief	EA	0.0	1.0	1.0	0.0	0.0	0.4
SK	R&D Tax credit	TC	-1.0	1.0	1.0	-1.0	-1.0	-0.2

Country	Instrument	Tax incentive*	Decision time	Electronic application	One-stop application	Public consultation	Evaluation	Organization total
UK	R&D Allowance	AD	0.0	1.0	1.0	1.0	-1.0	0.4
UK	R&D Relief	EA	0.5	1.0	1.0	1.0	-1.0	0.5
UK	R&D Relief	TC	0.0	1.0	1.0	1.0	-1.0	0.4
UK	The Patent Box	PB	0.0	1.0	1.0	1.0	-1.0	0.4
US	Credit for Incr. Res. Act.	TC	0.0	1.0	1.0	-1.0	0.0	0.2
US	Orphan drug research credit	TC	0.0	1.0	1.0	-1.0	0.0	0.2
US	Section 174 tax deduction	AD	0.0	1.0	1.0	-1.0	0.0	0.2
US	Special tax credit schedules	TC	0.0	1.0	1.0	-1.0	0.0	0.2
US	State R&D tax incentives	TC	0.0	1.0	1.0	-1.0	0.0	0.2

* AD = accelerated depreciation; EA = enhanced allowance; HY = hybrid; PB = patent box; RR = reduced tax rate; TC = tax credit

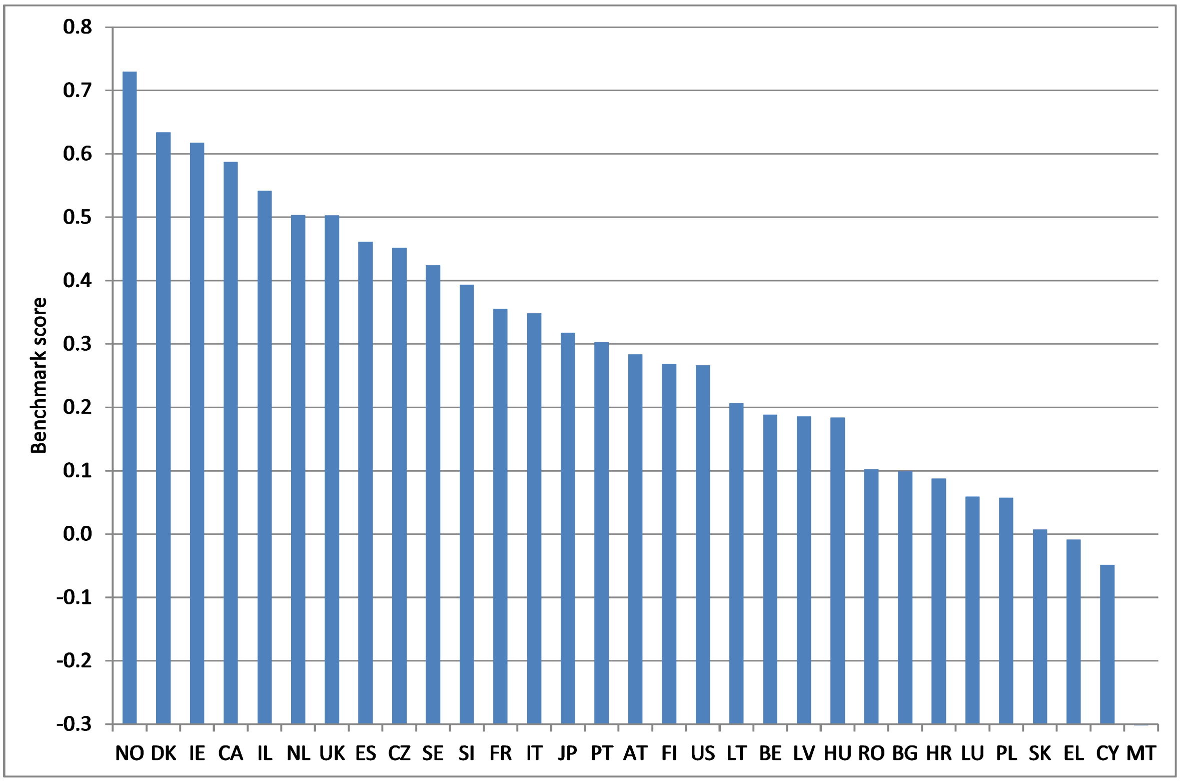
Annex 5. Complete ranking of R&D tax incentives

Instrument name	Country	Overall rank	(score)	Scope rank	(score)	Targeting rank	(score)	Organization rank	(score)
Jeunes Entreprises Innovantes	FR	1	(0.77)	1	(1.00)	16	(0.67)	3	(0.60)
SkatteFUNN	NO	2	(0.73)	26	(0.40)	61	(0.39)	1	(0.80)
Accelerated amortization	DK	3	(0.67)	66	(-0.10)	5	(0.78)	1	(0.80)
SR&ED	CA	4	(0.66)	3	(0.80)	50	(0.44)	14	(0.55)
WBSO	NL	5	(0.65)	9	(0.60)	48	(0.50)	3	(0.60)
R&D Tax Credit	IE	6	(0.62)	49	(0.27)	5	(0.78)	3	(0.60)
Capital Investments	IL	7	(0.61)	26	(0.40)	37	(0.56)	3	(0.60)
R&D Relief	UK	8	(0.60)	9	(0.60)	36	(0.61)	15	(0.50)
R&D tax allowance	IL	9	(0.59)	26	(0.40)	50	(0.44)	3	(0.60)
Skattekreditordningen	DK	9	(0.59)	26	(0.40)	50	(0.44)	3	(0.60)
Credit for R&D personnel	ES	11	(0.57)	9	(0.60)	1	(0.89)	16	(0.40)
R&D Relief	UK	12	(0.57)	3	(0.80)	37	(0.56)	16	(0.40)
RDA	NL	13	(0.56)	50	(0.20)	37	(0.56)	3	(0.60)
SR&ED	CA	14	(0.55)	9	(0.60)	5	(0.78)	16	(0.40)
Provincial R&D tax incentives	CA	15	(0.55)	2	(0.82)	47	(0.53)	32	(0.38)
Deduction for R&D wages	FI	16	(0.54)	26	(0.40)	82	(0.11)	3	(0.60)
New Tax Relief	PL	17	(0.54)	9	(0.60)	16	(0.67)	16	(0.40)
R&D Allowance	UK	18	(0.52)	9	(0.60)	37	(0.56)	16	(0.40)
R&D super deduction	CZ	19	(0.52)	62	(0.00)	37	(0.56)	3	(0.60)
Volume credit	ES	20	(0.51)	26	(0.40)	5	(0.78)	16	(0.40)
R&D tax relief	SI	20	(0.51)	26	(0.40)	5	(0.78)	16	(0.40)
R&D equipment credit	ES	22	(0.48)	50	(0.20)	1	(0.89)	16	(0.40)
Allowance for investment	SI	23	(0.47)	26	(0.40)	37	(0.56)	16	(0.40)
Decreto Destinazione Italia	IT	24	(0.46)	9	(0.60)	76	(0.22)	16	(0.40)
Crédit d'Impôt Recherche	FR	25	(0.46)	3	(0.80)	5	(0.78)	34	(0.20)
Incremental credit	ES	26	(0.46)	50	(0.20)	5	(0.78)	16	(0.40)
Innovation Tax Credit	ES	27	(0.44)	50	(0.20)	16	(0.67)	16	(0.40)
Payroll tax deduction for R&D	BE	28	(0.43)	9	(0.60)	1	(0.89)	34	(0.20)
Reduced soc. sec. contrib.	SE	29	(0.42)	3	(0.80)	37	(0.56)	34	(0.20)
Priority Areas	IL	30	(0.42)	67	(-0.20)	76	(0.22)	3	(0.60)
ABLL	JP	31	(0.39)	9	(0.60)	16	(0.67)	34	(0.20)
SIFIDE II	PT	32	(0.39)	9	(0.60)	35	(0.62)	34	(0.20)
R&D centers CIT relief	CZ	33	(0.38)	76	(-0.40)	62	(0.33)	3	(0.60)
Accelerated depreciation	IT	34	(0.38)	26	(0.40)	16	(0.67)	33	(0.25)
CSZL	JP	35	(0.35)	26	(0.40)	16	(0.67)	34	(0.20)
Super deduction	RO	36	(0.34)	9	(0.60)	62	(0.33)	34	(0.20)
The Patent Box	UK	37	(0.33)	67	(-0.20)	37	(0.56)	16	(0.40)
Patent box	ES	38	(0.31)	76	(-0.40)	5	(0.78)	16	(0.40)
R&D tax incentives for SMEs	JP	39	(0.31)	26	(0.40)	50	(0.44)	34	(0.20)

Instrument name	Country	Overall rank	(score)	Scope rank	(score)	Targeting rank	(score)	Organization rank	(score)
CSZL	JP	40	(0.30)	50	(0.20)	16	(0.67)	34	(0.20)
Section 174 tax deduction	US	40	(0.30)	50	(0.20)	16	(0.67)	34	(0.20)
General tax credit system	JP	42	(0.29)	48	(0.30)	48	(0.50)	34	(0.20)
Orphan drug research credit	US	43	(0.29)	26	(0.40)	62	(0.33)	34	(0.20)
Innovatiebox	NL	44	(0.29)	67	(-0.20)	62	(0.33)	16	(0.40)
Forschungsprämie	AT	45	(0.28)	26	(0.40)	75	(0.28)	34	(0.20)
Reduced soc. sec. contrib.	HU	46	(0.27)	9	(0.60)	5	(0.78)	52	(0.00)
CSZL	JP	47	(0.26)	50	(0.20)	50	(0.44)	34	(0.20)
Wages Tax Allowance	HU	48	(0.25)	9	(0.60)	16	(0.67)	52	(0.00)
Credit for Incr. Res. Act.	US	49	(0.25)	62	(0.00)	16	(0.67)	34	(0.20)
State R&D tax incentives	US	50	(0.25)	60	(0.13)	50	(0.44)	34	(0.20)
Special tax credit schedules	US	51	(0.24)	50	(0.20)	62	(0.33)	34	(0.20)
Patent box	PT	52	(0.22)	67	(-0.20)	5	(0.78)	34	(0.20)
Accelerated depreciation	LT	53	(0.22)	9	(0.60)	50	(0.44)	52	(0.00)
Patent box	FR	54	(0.21)	76	(-0.40)	82	(0.11)	16	(0.40)
Enhanced allowance	HU	55	(0.20)	26	(0.40)	16	(0.67)	52	(0.00)
Depreciation allowance	SI	55	(0.20)	26	(0.40)	16	(0.67)	52	(0.00)
Accelerated tax depreciation	BG	55	(0.20)	26	(0.40)	16	(0.67)	52	(0.00)
300% super deduction	LT	58	(0.20)	9	(0.60)	62	(0.33)	52	(0.00)
Tax credit researchers	IT	58	(0.20)	9	(0.60)	62	(0.33)	52	(0.00)
Enhanced allowance	LV	60	(0.19)	26	(0.40)	37	(0.56)	52	(0.00)
In-house R&D inv. deduction	BE	61	(0.16)	3	(0.80)	16	(0.67)	70	(-0.20)
Enhanced allowance for R&D	EL	61	(0.15)	26	(0.40)	62	(0.33)	52	(0.00)
New Technology Tax Relief	PL	63	(0.14)	50	(0.20)	37	(0.56)	52	(0.00)
In-house R&D inv. deduction	BE	64	(0.11)	9	(0.60)	16	(0.67)	70	(-0.20)
Technical feasibility	HR	65	(0.10)	26	(0.40)	1	(0.89)	70	(-0.20)
Enhanced allowance for R&D	HR	66	(0.08)	26	(0.40)	5	(0.78)	70	(-0.20)
Tax exemption IP income	LU	67	(0.06)	67	(-0.20)	16	(0.67)	52	(0.00)
R&D expenditure write-off	BG	67	(0.06)	67	(-0.20)	16	(0.67)	52	(0.00)
Patent Income Deduction	BE	67	(0.06)	67	(-0.20)	16	(0.67)	52	(0.00)
Remission of the CIT	BG	70	(0.04)	62	(0.00)	76	(0.22)	52	(0.00)
Patent Box	HU	71	(0.01)	76	(-0.40)	16	(0.67)	52	(0.00)
R&D Tax credit	SK	72	(0.01)	26	(0.40)	62	(0.33)	70	(-0.20)
Accelerated depreciation	FI	73	(-0.01)	50	(0.20)	37	(0.56)	70	(-0.20)
Crédit d'Impôt Innovation	FR	74	(-0.02)	3	(0.80)	50	(0.44)	80	(-0.40)
Enhanced allowance	CY	75	(-0.02)	76	(-0.40)	50	(0.44)	52	(0.00)
Patent box	CY	76	(-0.07)	82	(-0.60)	50	(0.44)	52	(0.00)
Tax Exemption SEZ	PL	77	(-0.09)	62	(0.00)	74	(0.30)	70	(-0.20)
Accelerated depreciation	RO	78	(-0.14)	26	(0.40)	62	(0.33)	80	(-0.40)
Tax Exemption R&D Centers	PL	79	(-0.14)	67	(-0.20)	62	(0.33)	70	(-0.20)

Instrument name	Country	Overall rank	(score)	Scope rank	(score)	Targeting rank	(score)	Organization rank	(score)
Tax Deduction R&D Centers	PL	80	(-0.15)	67	(-0.20)	76	(0.22)	70	(-0.20)
Outcome incentive	EL	81	(-0.17)	76	(-0.40)	50	(0.44)	70	(-0.20)
R&D tax credit	MT	82	(-0.23)	61	(0.10)	76	(0.22)	80	(-0.40)
Royalty Income from Patents	MT	83	(-0.39)	82	(-0.60)	76	(0.22)	80	(-0.40)

Annex 6. Average benchmark score per country



Note: The benchmark scores for countries were computed as the simple average over the instruments in a country. This implies that small instruments were given the same weight as instruments that have large budgets. Weighting instruments by their budgets or by the number of firms using them would give a more precise representation of how well a country performs, but this approach is not feasible due to a lack of information.

Annex 7. Ratings for 10 countries ranked highest by overall score

Country	Overall		Scope		Targeting		Organization	
	rank	(score)	rank	(score)	rank	(score)	rank	(score)
Norway	1	(0.73)	8	(0.40)	23	(0.39)	1	(0.80)
Denmark	2	(0.63)	23	(0.15)	9	(0.61)	2	(0.70)
Ireland	3	(0.61)	17	(0.27)	3	(0.78)	3	(0.60)
Canada	4	(0.59)	2	(0.74)	10	(0.58)	7	(0.44)
Israel	5	(0.54)	19	(0.20)	21	(0.41)	3	(0.60)
United Kingdom	6	(0.50)	7	(0.45)	11	(0.57)	8	(0.43)
Netherlands	7	(0.50)	19	(0.20)	17	(0.46)	6	(0.53)
Spain	8	(0.46)	19	(0.20)	2	(0.80)	9	(0.40)
Czech Republic	9	(0.45)	28	(-0.20)	18	(0.44)	3	(0.60)
Sweden	10	(0.43)	1	(0.80)	13	(0.56)	13	(0.20)

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KP-AC-14-052-EN-N

Publications Office

ISBN 978-92-79-44562-0
doi:10.2778/447538