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Measuring R&D tax support: Findings from the new OECD R&D Tax Incentives Database

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Foreword

This report is the result of work conducted under the OECD's Working Party of National Experts on Science and Technology Indicators (NESTI) project on "Measuring the use and impacts of government support for Research and Development", carried out in partnership with the OECD Committee for Scientific and Technological Policy and the OECD Committee on Industry Innovation and Entrepreneurship. This project has also benefited from financial support from the EU's Horizon 2020 Programme.

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Abstract

Investment in research and experimental development (R&D) is a key factor driving innovation and economic growth. Over the past two decades, tax incentives have become a widely used policy instrument for promoting R&D among businesses. This raises a number of policy questions: How has the role of R&D tax incentives in the R&D support policy mix evolved over time across OECD countries and other major economies? How generous are different tax relief provisions for different types of firms? How effective are they in stimulating additional business R&D investment?

The OECD R&D Tax Incentives Database (http://oe.cd/rdtax) aims to contribute to the data infrastructure available to policy makers and researchers to examine the use and impact of R&D tax incentives across OECD countries and partner economies over time. This paper provides a practical guide to using this new database, describing the recently released R&D tax incentive time series data and highlighting their potential for internationally comparative work through descriptive indicators and econometric analysis.

Executive Summary

Incentivising and providing the conditions for R&D investment by businesses ranks high on the innovation policy agenda of OECD countries and partner economies. How best to achieve this objective is a major policy question. In addition to providing direct funding for R&D through instruments such as grants and public procurement, many countries also provide indirect support through the tax system. Over the last couple of decades, there has been a proliferation in the use of R&D tax incentives by governments as a key instrument in their policy toolbox for inducing higher levels of business R&D expenditure. The heterogeneity in the design of R&D tax provisions across countries and the lack of comparable evidence on their translation into the actual amount of support received by firms, has hampered, until recently, the cross-country analysis of the impact of government tax support for R&D.

The ***OECD R&D Tax Incentives Database***[1] is the result of 10 years of close collaboration with a network of official experts from OECD countries and partner economies, coordinated by the OECD Working Party of National Experts on Science and Technology Indicators (NESTI) as part the Programme of Work and Budget of the OECD Committee for Scientific and Technological Policy. In recent years, such efforts have been stepped up with support from the European Union's Horizon 2020 Programme, which has contributed to an increased frequency of data collection and extended coverage and analysis.

This brand new edition of the *OECD R&D Tax Incentives Database* brings together two complementary sets of indicators on R&D tax incentives that facilitate a better integrated view of government support for business R&D across countries and, for the first, over time:

- Estimates of the **cost of Government Tax Relief for R&D** (GTARD): Covering 36 OECD countries and 11 partner economies, this indicator reflects how much governments spent on R&D tax support during the 2000-16 period, comprising both foregone tax revenues and refunded amounts. For the first time, a consistent time series of this indicator has been made available.
- Estimates of the **implied marginal R&D tax subsidy rate** (1-*B-Index*) faced by firms of different firm size (SMEs and large firms) and profitability (profit-making and loss-making): Covering 36 OECD countries and 8 partner economies during the 2000-18 period, the *B-Index* indicator that underpins these estimates is a synthetic measure of multiple tax incentive design features that define the implied tax subsidy rate for an additional unit of R&D investment.

This document provides an **overview of this database** and presents the two key indicators of government tax relief, highlighting their linkages and complementarities. While notional R&D tax subsidy rates offer a comparison of the design features and generosity of R&D tax incentives across countries, GTARD compares the actual amount of tax support provided by governments. The time-series of the cost of tax support in combination with that of direct funding illustrates key aspects of the **policy-mix** used by governments to support R&D. The descriptive analysis shows that the last two decades have been marked by an increase in the availability and uptake of R&D tax provisions and an increase in implied marginal R&D tax subsidy rates. The data show, with few exceptions, a generalised shift towards a greater reliance on tax support vis-à-vis direct support across countries.

In addition to presenting the database and its main indicators, this paper also seeks to highlight its potential as an analytical tool for assessing the effectiveness of R&D tax incentives in stimulating additional business R&D investment. It presents the results of a cross-country analysis of the **link between government support of R&D – direct and tax support–and business R&D** in OECD member countries over the 2000-16 period.

This analysis adopts two approaches: The first approach follows the literature in estimating the **price-elasticity of R&D** and yields short-run elasticities ranging from -0.11 to -0.12. This suggests that reductions in the price of R&D through tax incentives are linked to increases in business-funded R&D expenditure. The second approach, new to the macro literature, directly explores the **aggregate response of business R&D to the actual amount of government tax relief** provided to businesses, using the newly released time series on tax expenditure data. The results indicate a positive elasticity of business-funded BERD to the cost of tax incentives (foregone tax revenue or refund equivalent) of 0.02 to 0.04 in the short-run. Results are robust to the inclusion of statutory corporate income tax and real long-term interest rates as additional control variables, and are specific to R&D investment by firms, with no visible association with investment in other asset categories.

Policy-makers interested in assessing the capacity of R&D tax incentives to induce *additional* levels of business R&D expenditure in the economy will find in this paper two alternative estimation methods and results on the R&D **input additionality** of government support. Estimated gross **R&D incrementality ratios** (RDIR) for tax incentives range from 0.18 (when the traditional indirect approach is used based on the user cost of R&D) to 0.88 (using actual data on the contemporary cost of tax support). These estimates suggest that tax incentives are associated with additional R&D spending but involve some degree of crowding out, i.e. firms add to R&D proportionally less than the money they receive in compensation. This compares to RDIRs from 0.85 to 1.18 in the case of direct support, which is less precisely estimated, probably due to the wider range of direct funding instruments and implementation practices. While direct support, as in many country-level studies, is considered an exogenous policy variable, tax support is recognised to be potentially endogenous. When the endogeneity of tax support is taken into account, the results suggest that R&D tax incentives may have a fiscally neutral or even a net additional effect among countries where tax expenditures respond to policy design changes (RDIR=1.6).

Across the board, these results imply that the additionality of direct support might be on average slightly higher than for tax incentives. This finding, consistent with the literature, can be explained by the fact that most R&D tax incentives are provided on a non-discretionary basis. This does not imply that R&D tax incentives are a suboptimal policy choice. While direct support measures can be in principle oriented towards activities with greater additionality, constraints apply as they might run counter to competition and trade rules—that R&D tax incentives can be more easily rendered compliant with. In conducting an overall cost-benefit assessment, it is also important to take into account the actual costs of allocating resources on a discretionary basis as well as its potential pitfalls. An optimal policy mix is likely to require a combination of discretionary and non-discretionary support elements.

The results in this study showcase the potential of this new database as a **resource for policy and research**. Its public release opens new avenues for empirical research in this area that can widen the evidence-base on R&D tax incentives and help shape future policy. Since R&D tax incentives are complex objects of study, the combination of methods for their measurement and assessment is necessary. The OECD looks forward to continuing work with data providers and users to maintain and further enhance the relevance and usefulness of the OECD R&D tax incentive database.

1. Introduction

Investment in research and development (R&D) is a key driver of innovation and economic growth. In order to incentivise business R&D investment, governments combine diverse instruments that reduce the cost and uncertainty of performing R&D. Direct forms of support such as procurement, subsidies or grants are usually combined with indirect forms of support offered through the tax system. R&D tax incentive provisions have proliferated among OECD countries in recent years consolidating its position as a key instrument in governments' policy toolbox to promote business R&D. The heterogeneity in the design of R&D tax provisions across countries and the lack of comparable evidence on their translation into the relief actually received by firms has hampered, until recently, the creation of a data infrastructure to facilitate the cross-country analysis of the use and impact of R&D tax incentives in promoting business R&D.

As part of a long-term strategy to better capture the role of R&D and innovation policies more broadly, the OECD Directorate for Science, Technology and Innovation has collected information–via its Working Party of National Experts on Science and Technology Indicators (NESTI**)**–on both the cost and design of R&D tax incentives on a systematic basis since 2007. A dedicated survey of official national contacts on R&D tax incentives, last carried out in 2018, provides the information used to construct the database.

Thanks to the efforts and the broad participation of official experts from OECD countries and partner economies, it has been possible to produce and regularly update a series of indicators of government support for business R&D and the implied generosity of tax relief provisions.[2] The *OECD R&D Tax Incentives Database* (OECD, 2018[1]) is the result of this collaborative data collection effort. This database makes available for the first time a curated time series of estimates of Government Tax Relief for R&D (GTARD) and implied marginal R&D tax subsidy rates based on the *B-Index*. These two time series provide a complementary picture of governments' efforts to incentivise business R&D through the tax system:

- The GTARD data series constitutes the first internationally comparable time series of R&D tax expenditures at the aggregate 'macro' level, reflecting the actual cost of R&D tax support to the central government. Data are currently available for 36 OECD member states and 11 partner economies[3] for the 2000-16 period. The experiences accumulated over past series of data collections have also fed into the 2015 edition of the OECD Frascati Manual (OECD, 2015[2]) which, for the first time, included guidelines on the measurement of the cost of government tax relief for R&D alongside traditional indicators of direct funding.
- The *B-Index* time series provide an estimate of the implied R&D tax subsidy rate (1 minus *B-Index*) faced by firms of different firm size (SMEs and large firms) and profitability (profit-making and loss-making). Measures of tax subsidy rates such as those based on the *B-Index* provide a model-based synthetic representation of the implied generosity of a tax system. Data are currently available for the 36 OECD member countries and 8 partner economies[4] for the 2000-18 period.

To provide a more complete picture of governments' efforts to promote business R&D, the OECD R&D tax database also includes estimates of direct funding of business R&D (BERD). Estimates of direct funding of BERD are reported by firms in national business R&D surveys and published as part of the OECD Main Science Technology Indicators (MSTI) database (OECD, 2018[3]), based on the OECD R&D Statistics (RDS) database (https://oe.cd/rds). The OECD RDS database is the outcome of the international data collection of R&D statistics carried out by OECD since the 1960s. The *B-Index* and combined GTARD and direct funding data series will also feature in the OECD Corporate Tax Statistics database (https://oe.cd/corporate-tax-stats), launched by the OECD Centre for Tax Policy and Administration in January 2019.

The *OECD R&D Tax Incentives Database* aims to contribute to the data infrastructure available to policy makers and researchers to examine the use and impact of R&D tax incentives across OECD countries and partner economies over time. In order to demonstrate the potential of the database for both descriptive and further analytical applications, this paper provides a new analysis on the use and potential impact of R&D tax incentives across OECD member countries and partner economies.

This paper presents an aggregate-level analysis of the likely effectiveness of R&D tax incentives in generating additional R&D spending (input additionality) across OECD countries over the 2000-16 period. This analysis, principally intended for demonstration purposes, helps provide insights into the advantages of combining different measures of government tax relief with measures of direct support into a cross-country framework. Because macro level analysis entails a number of challenges due to the lack of long time series and the limited granularity of the data, the OECD is also concurrently conducting a distributed microdata analysis project (microBeRD) that investigates and exploits variation at much lower levels of data aggregation across countries participating in this project[5]. Both strands of work should be considered as complementary.

The report is organised as follows: **Section 2.** provides some additional background on the *OECD R&D Tax Incentives Database*, including a brief introduction to the measurement of GTARD and calculation of implied marginal R&D tax subsidy rates base on the *B-Index*. This is followed by discussion of how average tax subsidy rates based on GTARD relate to those based on the synthetic *B-Index* measure. **Section 3.** presents descriptive evidence on the use of R&D tax incentives based on the latest GTARD and *B-Index* estimates available. This section aims to shed light on recent and long-term trends in the use of R&D tax incentives and the rate of R&D tax subsidy across OECD countries and partner economies. **Section 4.** contains new OECD analysis on the effectiveness of R&D tax incentives in inducing additional business R&D investments, exploiting the new GTARD and *B-Index* time series from the *OECD R&D Tax Incentives Database*. This includes a discussion of available methods to estimate the R&D incrementality ratio – a measure of input additionality – in macro-level studies, and an application to the group of OECD countries included in the OECD database. **Section 6.** concludes with a summary of the main findings, their potential implication and future OECD work in this area.

2. Measuring tax support for R&D and innovation

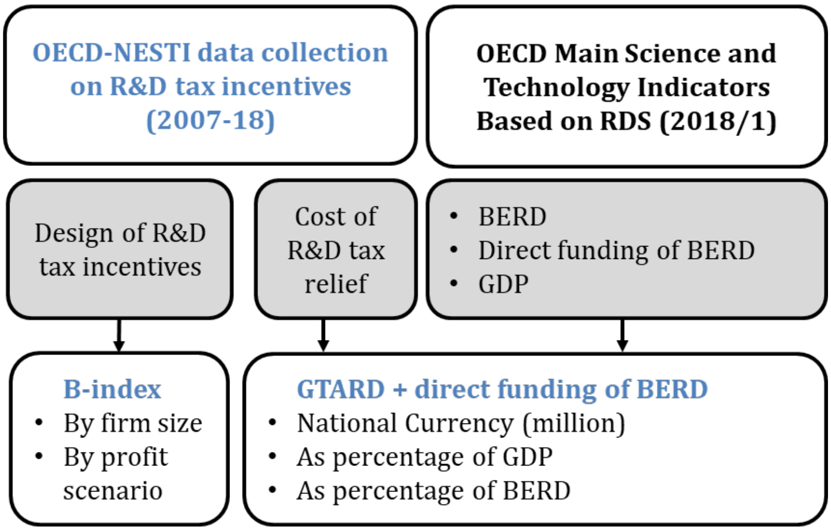
Governments provide financial support for business R&D through several instruments, including R&D tax incentives. Support provided through this instrument went largely underreported in international statistics until 2007, when the OECD started the systematic collection of information on both the cost of R&D tax incentives and the design of these schemes through a dedicated survey complementing its regular data collection on R&D statistics.[6] In 2015, the reporting frequency shifted to an annual basis, thus enabling the publication of more timely data.

The OECD-NESTI data collection on R&D tax incentives attempts to identify the full range of relevant differences in the tax treatment of R&D, including the relevant tax benchmark and reporting approaches adopted by national authorities. In order to fulfil the OECD information request, country-level reporting entails a collaboration between national experts on science and technology indicators with public finance and tax authorities. The engagement of this informal *OECD expert network on R&D tax incentives* allows the provision the most up-to-date and internationally comparable figures and up-to-date information on the cost and design of R&D tax incentives.

The *OECD R&D Tax Incentives Database* released in November 2018 presents the first internationally comparable, curated time series of GTARD and the *B-Index* developed as part of this long-term, collaborative data collection and reporting effort. **Figure 1** summarises the structure of the database, including sources of data and available indicators.

Figure 1. The OECD R&D Tax Incentives Database, 2018 edition

http://oe.cd/rdtax



Note: The OECD MSTI R&D indicators are based on the R&D data reported in http://oe.cd/rds. The database uses direct funding data reported by business as opposed to data reported by government funders. The latter would be more consistent with GTARD data, which is government-reported, but it is currently not available broken down by beneficiary for a majority of countries. In addition to substantive annual updates on its core information, the database is subject to additional minor updates in order to ensure full alignment with R&D statistics published by OECD and other normalising variables such as GDP.

The database further includes estimates of direct funding of BERD, reported by firms in national business R&D surveys and published as part of the *OECD Main Science Technology Indicators* (MSTI) database (OECD, 2018[3]). Those estimates[7], combined with GTARD, provide a more comprehensive picture of governments' efforts to promote R&D investment by business

2.1. Government tax relief for business R&D (GTARD)

Measuring how much governments dedicate to support R&D through R&D tax incentives involves a number of conceptual and practical challenges, especially when attempting to do so in an internationally comparable fashion. GTARD, reported by national experts, focusses solely on capturing the cost of provisions that imply a more favourable treatment of R&D relative to other non-R&D specific expenditures. In other words, GTARD captures the enhanced treatment of R&D, over and above the baseline treatment of other comparable business expenses or investments (OECD, 2015[2]).

Measuring tax expenditures for R&D thus requires agreement on a common benchmark on what represents the baseline tax treatment of R&D expenditures. In the absence of enhanced incentives, companies generally have the ability to report current expenditure components of R&D as deductible costs of sales, without necessarily identifying the R&D nature of the activity. This approach ensures the comparability with countries that do not report dedicated R&D tax relief but allow for the deductibility of current R&D expenses. An exception may arise when companies capitalise the current R&D expenditures.[8]

The estimation of the value of tax relief provided for R&D falls under the responsibility of national governments, which report to the OECD following as closely as possible the guidelines provided. The 2015 *OECD Frascati Manual* (OECD, 2015[2]), which for the first time provides guidelines on the measurement of government tax relief for R&D (GTARD), aims to provide a common and meaningful perspective that is consistent with different national R&D tax relief and data source systems. OECD GTARD estimates have the following scope when measuring the cost of tax relief (OECD, 2018[4]):

- *Relief for R&D inputs*: Definitions of R&D or other types of expenditures eligible for tax relief differ across jurisdictions and with respect to the definition provided in the *OECD Frascati Manual*[9], although in a number of instances the manual's definitions are part of the tax legislation.[10] The estimates of GTARD reported exclude income-based tax incentives – preferential treatment of incomes from licensing or disposal of assets attributable to R&D (e.g. patents) or other innovation activities.

- *Relief for business enterprises*: Estimates exclude incentives to taxpayers other than companies or individuals operating on such capacity. The business enterprise sector is usually the main intended direct recipient of tax relief for R&D. Provisions may allow relief for R&D subcontracted to third parties, in other domestic sectors such as higher education or located abroad. These can be included within the scope.

- *Relief provided by central (federal) government*: For practical reasons, only estimates of tax relief at central (or federal) level are included in this first edition. Future editions of the GTARD time-series will account for the cost of subnational R&D tax incentives, where applicable[11] and where relevant data are available.

Ensuring a common approach with respect to the recording of the costs of providing tax relief entails some challenges. In principle, this recording should occur when the R&D

eligible for tax relief has taken place; in practice, this may be possible only when the claim is recognised by government regardless of the time when it is paid in cash by government or used to decrease the tax liability of the firm. In many cases, tax authorities are only able to provide information based on payments, i.e. on a cash-based approach, which more closely follows the actual flow of money between authorities and tax-paying units.

Available estimates typically aim to reflect the sum of foregone tax revenues – on an accruals basis – and refunds where applicable, with no or minimal adjustments for behavioural effects. Some countries only report claims realised in a given year (cash basis), while others report losses to government on an accrual basis, excluding claims referring to earlier periods and including claims for current R&D to be used in the future. [12] This is the most challenging dimension of reporting for many countries and a challenge for international comparability given the uncertainty of such future costs, especially when companies do not have to report contemporaneously the current expenses that may give rise to future tax benefits. OECD (2018[4]) provides an extended discussion on the estimation and recording of tax relief for R&D, including measurement challenges.

In addition, some measurement challenges arise specifically in the compilation of time-series estimates of R&D tax expenditure:

- **Time-lag:** information on the cost of tax and direct support for R&D becomes available at different frequencies and the former typically with a time-lag of two to three years.
- **Data revisions**: to the extent that countries allow firms to carry-back unused tax benefits or claim those retrospectively, an update of cost estimates may be required over some time period. Such an update can affect multiple data points in the time-series.
- **Missing and incomplete estimates:** information on the cost of R&D tax incentives for a specific year may be missing or only partial, covering not all R&D tax relief instruments offered by a country in a given year.
- **Breaks-in series:** attention needs to be paid to the time-consistency of reported estimates of the cost of R&D tax relief. Breaks-in-series may arise as a result of changes in the estimation or projection method of R&D tax expenditure. This challenge is not specific though to GTARD data, as methodological revisions are also common to BERD data and its components.[13]

In accordance with the *Frascati Manual* guidelines, the OECD has produced a curated time-series of GTARD estimates that represents one key output of the OECD R&D Tax Incentives Expert Network's data collection and validation efforts. Based on GTARD, an average R&D tax subsidy rate can be obtained by scaling GTARD by BERD. This average tax subsidy provides an approximate measure of the *actual* amount of R&D tax relief provided to business relative to their R&D effort. It thus provides a complementary measure to the implied marginal R&D tax subsidy rate computed based on the *B-Index*.

2.2. Implied marginal R&D tax subsidy rates (1-*B-Index*)

In measuring tax support for R&D, it is important to understand the potential implications of tax relief provisions on the cost of performing R&D. Forward-looking measures of implied marginal R&D tax subsidy rates such as those based on the *B-Index* provide a convenient proxy measure for examining the implications of tax relief provisions which influence the average and marginal cost of R&D to firms. The *B-Index* indicator and its associated *Implied Tax Subsidy Rate* provide a synthetic representation of the generosity of the tax system from the perspective of a generic or model type of firm for a marginal unit of R&D expenditure.

Box 1. Understanding the *B-Index*

What is the B-Index and its Implied Subsidy Rate?

R&D tax relief provisions lower the cost faced by business that perform R&D or pay others to do so on their behalf. The *B-Index* helps identify the expected cost reduction or implied level of *tax subsidy for one extra unit of R&D* invested by firms (Warda, 2001[5]; OECD, 2013[6]). What the *B-Index* literally identifies is a closely related concept: the pre-tax return required for a firm to financially break-even, following a decision to spend one additional monetary unit on R&D, taking into account how much tax is ultimately due. The more generous the tax provisions for R&D, the lower the *before-tax* breakeven economic return required by firms (i.e. the *B-Index*) and therefore the higher the implied marginal *R&D tax subsidy*. For this reason, it is customary to present this indicator in the inverse form of an *Implied Subsidy Rate*, expressed as 1 minus the *B-Index*.

How is the B-Index calculated?

In its simplest formulation, the *B-Index* is modelled and computed for a representative firm as the after-tax cost (ATC) of one additional unit of R&D expenditure, normalised by one minus the corporate income tax rate, so that numbers can be expressed in "before tax" terms. A 'representative firm' in the simplest instance is one with sufficiently large profits to be able to fully exercise the earned tax benefits in the reporting period. In such a case, the *B-Index* value that makes marginal benefits and costs of R&D identical, and its implied subsidy rate, can be expressed as:

$$B\ Index \coloneqq \frac{\mathrm{ATC}}{1-\tau} = \frac{1-\mathrm{A}}{1-\tau} \qquad (1)$$

$$Implied\ Subsidy\ Rate \coloneqq 1 - B\ Index = \frac{\mathrm{A}-\tau}{1-\tau} \qquad (1')$$

The numerator of the *B-Index* represents the after-tax cost (ATC) of investing one unit of R&D accounting for all tax provisions in place. In this expression, '*A*' is the combined net present value of tax allowances and credits applying to the marginal R&D outlay and 'τ' is the corporate tax rate. The denominator converts the *after-tax* numerator into *pre-tax* terms, allowing the comparison across countries with different tax rates. The term *A* is calculated using key design features of R&D tax incentives and the general tax system, as explained in the main body of the text.

A simple illustration

In the case of an enhanced, volume-based R&D tax allowance 'θ' (deduction from taxable profits) of 50% on the entire current R&D expenditure for a firm which for simplicity does not have R&D capital expenditures, the calculation of *A* will reflect that current expenditures are by default fully deductible - the benchmark scenario in most countries. In that case: $A=\tau+\tau*\theta=\tau*150\%$ and the Implied Subsidy Rate=50%*τ/(1- τ). In contrast, if no enhanced deductions for R&D are in place, then $A=\tau$, the *B-Index* equals 1 and the subsidy rate is zero.

If a company is instead eligible for a tax credit 'c' of 10%, then $A=\tau+c$ and the Implied Subsidy Rate=10%/(1- τ). These examples show that different tax provisions can be modelled and rendered comparable through the *B-Index* indicator and its Implied Subsidy Rate counterpart. Furthermore, it is possible to note that for any given tax rate, e.g. 20%, the same notional subsidy can be granted with different instruments (i.e. 50% enhanced allowance or a (non-taxable) tax credit of 10%).

Box 1 provides a summary introduction to the *B-Index* indicator, highlighting its most basic and key defining features. **Annex A** presents some additional examples that further illustrate the *B-Index* calculation. As shown in **Box 1**, the *B-Index* and its *Implied Subsidy Rate* are synthetic indicators that capture and 'quantify' in a simple yet meaningful fashion a number of qualitative and quantitative but heterogeneous features of R&D tax incentives and the national tax system. Additional attractive features of the *B-Index* relate to its interpretation as tax component of the user cost of R&D (OECD, 2018[7]) and its potential use to construct *Effective Tax Rates* indicators as used in the tax literature (OECD, 2019[8]).

The calculation of the *B-Index* used in this paper and the OECD database focuses on expenditure-based R&D tax incentives provided at central (federal) government level. In some countries like Canada, additional tax support for R&D at the subnational level can make a significant difference. Capturing this additional information is work in progress at OECD.

The modelling of tax incentives takes into account several aspects. First comes the definition of qualifying R&D expenditure and its relationship to actual R&D performance, since not all R&D activities may be subject to the same level of tax support relative to their non R&D benchmark. The normal default or benchmark position for tax systems is to allow R&D expenses to be fully deducted, regardless of the fact that they represent investments in developing knowledge assets. Indeed, absent specific regulatory requirements, it is generally not difficult for a company that wishes to do so to report current R&D expenses as general operating costs. Different regimes consider various types of current R&D expenses that may be eligible for tax support. For example, a key challenge for codification and modelling purposes concerns the treatment of expenses for costs incurred for R&D related activities carried out by third parties (domestic or based abroad) on behalf of the beneficiary. Conversely, some regimes may or may not provide relief to the firm that carries out R&D for a third party.

While current expenditures are typically fully deductible, capital expenditures are depreciated over their useful life in most countries. In the case of capital expenditures incurred as part of or in order to support R&D activity, this paper's modelling recognises that capital expenditures are not generally immediately deductible in the baseline. For this reason, countries without any form of tax support for R&D have a *B-Index* value higher than unity and as a result, a negative implied subsidy rate.[14] If capital expenditures are immediately deductible ($Z = 1$), capital costs can be treated as current R&D expenditure.

The *B-Index* estimates account for differences in the treatment of the various components of R&D expenditures - current (labour, other current) and capital (machinery and equipment, facilities/buildings) expenditures, adopting a common reference that reveals the average composition of R&D activity in the OECD area.[15] Modelling is also adjusted for differences in the types of taxes used by countries to administer the R&D support. Corporate tax income is the most common mechanism but not the sole one. Some countries use payroll taxes and employer social security contributions to administer support for R&D.

Incremental tax incentives, i.e. those where tax incentives only apply to the volume of eligible R&D in excess of a pre-defined base amount, are modelled by treating the marginal unit of R&D as above the base amount, considering that increasing R&D at a given time increases the future baseline R&D level and reduces the opportunity to benefit from future support (OECD, 2018[7]). This is formally equivalent to implementing adjustments to the credit or allowance rates, a correction that also needs to be made when modelling the provisions in countries that treat credits as taxable income.[16].

Another aspect addressed in the *B-Index* modelling relates to the type of incentive instrument applied, as tax relief can be provided in different forms, e.g. as an allowance, exemption, deduction or credit. The impact of "headline" tax relief rates will depend on the choice of instrument. Tax allowances, exemptions and deductions effectively reduce the taxable base before the tax liability is computed. A tax credit is an amount subtracted directly from the tax liability. In the case of relief for R&D, the usual default or benchmark position is to allow R&D expenses to be fully deducted, regardless of the fact that they represent (risky) investments in developing knowledge assets. Therefore, the term 'enhanced allowance' is used to identify provisions that represent a deduction rate of more than 100% over eligible expenses. As shown in **Box 1**, R&D tax credits can, ceteris paribus, be converted into R&D tax allowances that provide the same effective incentive and vice versa. However, once rates are set, the value of tax benefit will react differently to changes in the tax rate, the value of R&D tax allowances being directly linked to the level of the relevant tax rate. The interaction with other tax subsidies may also change as a result.

Firm size and profitability are two key business characteristics that influence the level of implied marginal R&D tax subsidy rates that applies to firms. To provide a more accurate representation of four relevant scenarios, the OECD *B-Index* estimates consider targeted tax relief provisions that grant a preferential treatment for SMEs compared to large firms (e.g. enhanced tax credit rates) and they also account for the different tax relief provisions that apply to 'loss-making firms'. These cannot fully exercise earned tax benefits in the current reporting period. When credits or allowances are fully refundable, the *B-Index* of a firm in such a position is identical to the profit scenario. Carry-forwards are modelled as discounted options to claim incentives in the future (OECD, 2018[7]).

Due to limited availability of historical information, the *B-Index* time-series estimates are not adjusted for provisions that impose limitations on the tax benefits received by firms (e.g. ceilings, thresholds). Marginal tax subsidy rates, calculated based on headline R&D tax credit (allowance) rates, they provide an upper bound value of the generosity of R&D tax incentives, not reflecting the effect of thresholds and ceilings that may limit the amount of qualifying R&D expenditure or the value of the R&D tax relief.

R&D grants and other direct subsidies generally reduce the expense base for calculating R&D tax relief by an amount equivalent to the subsidy received.[17] The current edition of *B-Index* time-series estimates does not yet model the treatment of grant-funded R&D projects and aggregation rules but it is expected to incorporate such important characteristics in future editions. Payroll and social security related incentives are effectively taxable as well, reducing the expense base and increasing firms' taxable income. These incentives have been consistently modelled.

2.3. Linking marginal and ex-post average R&D tax subsidy rates

One question of policy interest is the extent to which tax incentive design features change and therein influence the cost of government tax relief for business R&D (OECD, 2015[2]). One way to address this question is to examine the link between marginal R&D tax subsidy rates and ex-post average subsidy rates measured as pre-tax GTARD as a percentage of BERD. The comparison is undertaken on a *before-tax* basis to facilitate the comparability with the marginal tax subsidy measure which is expressed in such terms.

Implied marginal R&D tax subsidy rates, customarily derived as 1 minus the *B-Index*, specify the notional level of subsidy (before tax) on one additional unit of R&D outlay. As a measure of the user cost of R&D to the firm, the *B-Index* is a function of the main design features of tax incentives and general parameters of the tax system (e.g. statutory corporate income tax rates, baseline tax treatment of current and capital expenditure). Notional tax subsidy rates represent forward-looking tax subsidy rates for a hypothetical R&D investment and are independent of the demand (uptake) for the incentive and fluctuations in the level of R&D. These are relevant for R&D investment decisions at the intensive margin, i.e. how much R&D investment to incur.

The ex-post average subsidy rate represents in turn an average R&D tax subsidy measure which is relevant for R&D investments at the extensive margin (e.g. whether or not to invest in R&D in a given country). Ex-post average tax subsidy rates represent backward-looking tax subsidy rates. Computed as the total amount of tax relief received by firms as a percentage of total intramural R&D performed by business in the economy, this subsidy rate provides an approximate measure of the amount of tax relief that is provided on average on each unit of intramural R&D expenditure incurred by business. Changes in the ex-post average tax subsidy may reflect both changes in the design of R&D tax incentives and demand, i.e. the uptake of the incentives by firms and the level of eligible R&D expenditure incurred and claimed by business. As a demand-led policy instrument, the cost of tax support can be expected to fluctuate with the level of business R&D investments in different business-cycles. This makes GTARD endogenous to BERD.

Differences between the marginal R&D tax subsidy rate and the ex-post average GTARD-TO-BERD ratio can relate to several factors:

- The measurement of the *B-Index*;
- The measurement of the cost of tax support (GTARD) and BERD;
- Differences in the time perspective taken by each measure.

As **Section 2.2** explains, the *B-Index* calculation is based on certain modelling assumptions (OECD, 2018[7]) and excludes the tax treatment of personal income, value added and capital taxes. In contrast to GTARD, the current *B-Index* time-series does not account for the treatment of grant-funded R&D projects, aggregation rules and the presence of thresholds and ceilings[18]. This can drive a gap between marginal and average tax subsidy rates, depending on the position of the marginal unit of expenditure of different firms in relation to ceilings or thresholds.

A second measurement issue relates to the fact that the *B-Index* is theoretically derived for different firm size group (SME and large firms) and profitability (profitable and loss-making) scenarios. In order to establish a proper comparison with the ex-post average subsidy rate (which accounts for all firm-specific situations of profitability and size), a suitable set of weights for firm size and profitability are needed to aggregate the implied marginal subsidy rates across the four scenarios. The OECD microBeRD project aims to help address this measurement gap and provide micro-aggregated measures drawing on specific firm-level characteristics for countries where the relevant microdata are available.

The measurement of GTARD and BERD can also drive differences in marginal R&D tax subsidy rates and the ex-post average subsidy rates. GTARD estimates reflect the total relief earned by taxpayers within the current year (accruals basis) or total relief provided by government in the current year (cash basis). In the case of cash-based estimates, a misalignment may arise in timing at which specific design features apply and cash-payments are received by firms. R&D tax benefits are taxable in a number of jurisdictions and exemptions of payroll withholding tax and social security contributions are effectively taxable as they reduce the amount of expenditure deductible from taxable income. Several countries that offer taxable incentives appear to report GTARD gross of tax, leading to a further divergence of GTARD and *B-Index* estimates the latter of which account for the taxability of R&D tax benefits.

Differences in marginal tax subsidy rates and ex-post average subsidy rates may also be related to the normalisation of GTARD by BERD. If the scope of qualifying R&D expenditure is broader than BERD and includes extramural R&D, for instance, the GTARD-to-BERD ratio would overstate the actual R&D tax subsidy provided to firms on average.

Finally, implied marginal tax subsidy rates reflect the ex-ante notional rate of R&D tax subsidy for one additional unit of R&D outlay spent by a firm with specific characteristics. This ex-ante rate of tax support might not be realised by all firms ex-post for various reasons. Not all eligible firms necessarily apply or succeed in receiving tax support for a number of possible reasons (e.g. administrative and compliance costs, lack of awareness of tax relief measure).

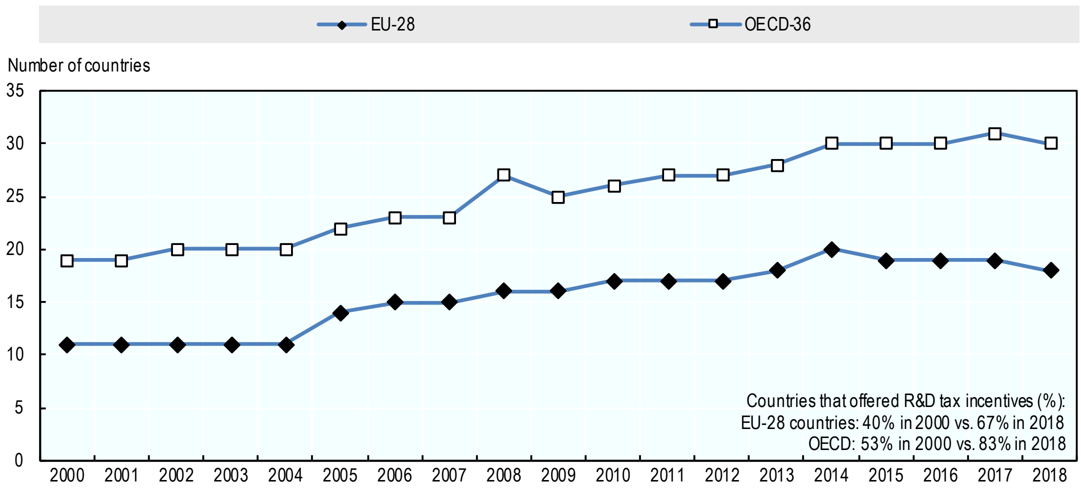
Future updates of the *B-Index* time-series will account for thresholds and ceilings to the extent to which countries can provide relevant data on the distribution of eligible R&D spending by SMEs and large firms with respect to such provisions. Additional data on business R&D by firm size and profit scenario, where available, would further facilitate a more suitably weighted average *B-Index* measure across the four scenarios considered and improve the alignment between ex-ante and ex-post R&D subsidy rates.

3. Evidence on the use of R&D tax incentives

3.1. Availability of R&D tax relief provisions

The OECD database shows that over the past two decades, many countries have increased the availability, simplicity of use and generosity of R&D tax incentives. More countries currently rely on tax support to encourage business R&D than ever before. In 2018, 30 out of 36 OECD countries give preferential tax treatment for business R&D expenditures, up from 19 OECD countries in 2000 (**Figure 2**). Eleven additional OECD countries launched tax incentives over this time period, excluding the temporary R&D tax incentive introductions by Finland (2013-14) and New Zealand (2008) and the temporary suspension of the SIFIDE R&D tax credit in Portugal (2004-05). In the EU, the number of countries offering R&D tax relief increased from 12 in 2000 to 21 in 2018.

Figure 2. Trends in the uptake of R&D tax incentives, OECD and EU, 2000-18



Note: EU-28 excludes Malta as no sufficiently detailed information is available on R&D tax relief provisions.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Among OECD countries, four have not offered R&D tax incentives during the 2000-18 period: Germany, Estonia, Luxembourg and Switzerland. In the EU, a proportionally larger fraction of countries has not used this policy instrument to stimulate business R&D over those years: Bulgaria, Cyprus, Estonia, Germany and Luxembourg.

3.2. Direct and tax subsidies for business R&D: a recent snapshot

3.2.1. GTARD compared to direct funding of BERD

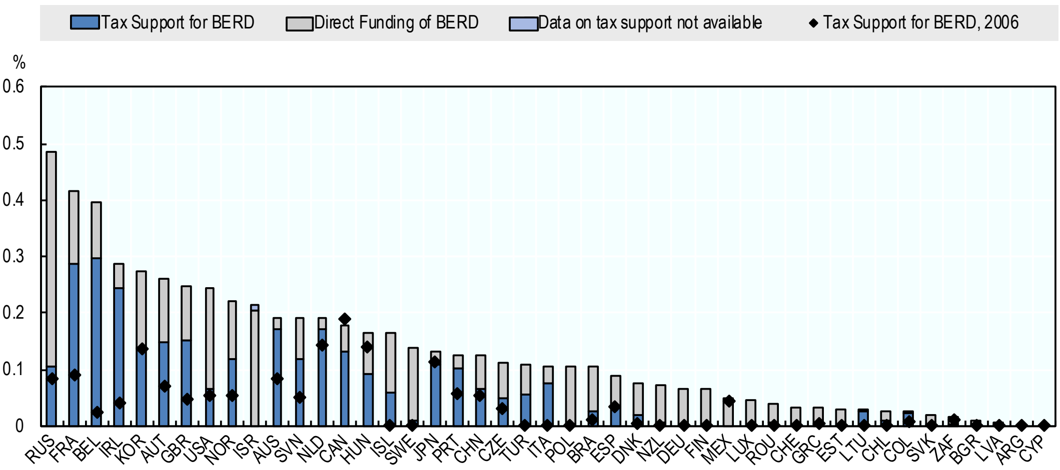
Governments often choose to combine different policy instruments in supporting business R&D. Direct funding of business R&D via procurement, grants and subsidies and tax relief to R&D stand as key support measures that differ both in their mechanism of application, their policy objective and their use.[19] On the one hand, direct support allows better targeting[20] of funds to specific projects with a high social return, albeit at a higher cost of administration. R&D tax incentives on the other hand, seek to reduce the cost of R&D to firms leaving to their discretion which R&D projects to undertake.

This section lays out the most recently available evidence on the cost of central (federal) government support for R&D through tax relief and direct funding measures. Combining both types of support (direct funding and tax relief) provides a more complete picture of governments efforts to incentivise business R&D and sheds light on the absolute and relative magnitude of direct and tax support across OECD countries and partner economies.

The data on the cost of tax support and direct funding in **Figure 3** refers to 2016 for 33 countries (including those providing no tax support), 2015 for 9 countries, 2014 for 2 countries and 2013 for 1 country. Data on R&D tax incentives are not available for 2016 (or closest year) for three countries (Israel, Croatia and Malta). In 2016, six OECD countries (Estonia, Finland, Germany, Luxembourg, Mexico and Switzerland) and three other EU countries (Croatia, Cyprus and Bulgaria) do not offer R&D tax incentives.

Figure 3. Direct government funding of business R&D and tax incentives for R&D

OECD and selected countries, 2016 or latest year, as percentage of GDP



Note: Data on the cost of tax support is not available for Israel.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

As a percentage of GDP, the Russian Federation, France and Belgium provided the largest combined (direct and tax) support for business R&D (**Figure 3**) in 2016, equivalent to 0.49%, 0.41% and 0.40% of GDP. The highest values of direct support as a percentage of GDP were attained in the Russian Federation (0.38%), Israel (0.21%), the United States (0.18%) and Korea (0.14%). The weighted average of direct support is equal to 0.10% of GDP in the OECD area. Direct support accounts for 6.3% of BERD in the OECD area.

As direct funding statistics do not account for tax support, their use in isolation can provide a misguided picture of the total level of government support available for business R&D in an economy. Some countries, which appear to offer little support on the sole basis of direct funding, do in fact provide significant assistance through the tax system. This is the case for countries such as Australia, Ireland, Japan and the Netherlands, where tax relief accounts for over 80% of total public support. In the OECD area, the share of tax relief in total government support increased on average from 36% in 2006 to 46% in 2016. This trend has been fairly homogenous among OECD countries with only a few exceptions, e.g. Canada and Hungary who, departing from a high share of tax support in 2006, rebalanced their policy-mix towards direct forms of support (**Figure B.1**).

OECD countries provided tax relief for business R&D of USD 45 billion in 2016. This figure rises to USD 64 billion when other selected economies (Argentina, Brazil, China, Colombia, the Russian Federation and South Africa) are included. In 2016, tax relief for R&D expenditures as a percentage of GDP is largest for Belgium (0.30%), France (0.29%), Ireland (0.25%), followed by the Netherlands (0.17%) and Australia (0.17%). The average rate of tax support in the OECD area - including countries that do not provide this type of support – equals 0.09% of GDP. The ex-post average R&D tax subsidy (GTARD-to-BERD ratio) amounts to 5.5% in the OECD area.

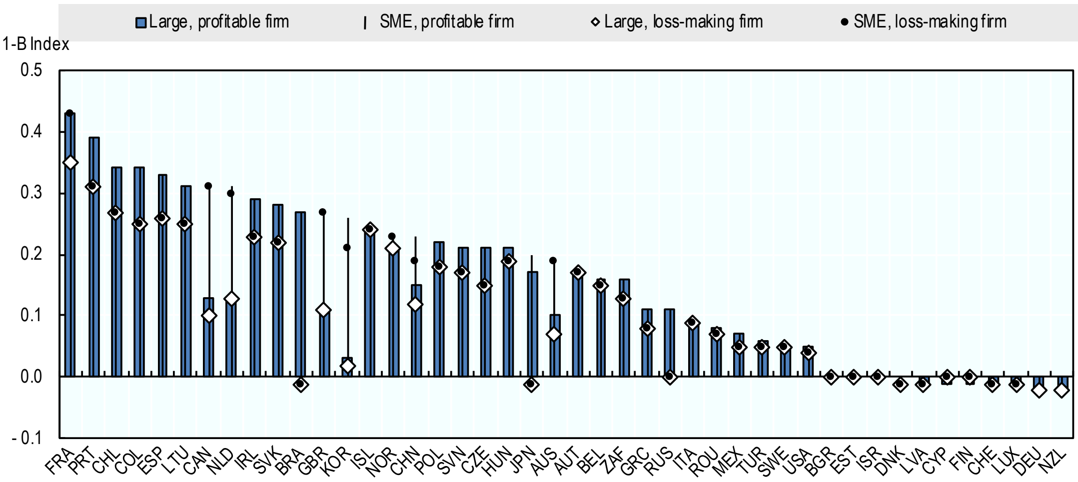
Over the 2006-16 period, tax support for business R&D expenditure as a percentage of GDP increased in 26 out of 44 countries for which data are available. New Zealand reintroduced R&D tax support in the form of an R&D tax credit for deficit-related R&D tax expenditure in 2015.[21] Mexico, which converted its previous R&D tax credit into direct funding in 2009, reintroduced R&D tax incentive support with effect from 2017. This recent reform is not yet reflected in the tax expenditure estimates available.

3.2.2. Implied marginal R&D tax subsidy rates

The design of R&D tax incentives varies greatly across countries (OECD, 2018[7]). The *B-Index* provides a convenient tool to compare the implications of tax relief provisions. The implied notional subsidy, *1 – B-Index*, provides a synthetic representation of the generosity of the tax system for a marginal unit of R&D outlay. **Figure 4** presents the 2018 implied marginal R&D tax subsidy rates by firm size and profitability scenario. These estimates are based on headline tax credit (allowance) rates and do not account for ceilings or thresholds that may limit the amount of eligible R&D expenditures or the value of tax benefits.

Figure 4. Implied tax subsidy rates on R&D expenditures, 2018

1-*B-Index*, by profit scenario and firm size, OECD and selected economies



Note: Figures reflect the tax treatment of R&D expenditure for SMEs and large enterprises in OECD, EU and other major economies. Some countries, but not all, offer tax incentive support for business R&D expenditure. No estimates are available for Argentina, Croatia and Malta. Figures do not reflect preferential provisions for start-ups, young firms or a specific subset of SMEs (e.g. innovative SMEs).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

In 2018, these notional tax subsidy rates are highest for profitable SMEs and large firms in France, Portugal and Chile (0.43, 0.39 and 0.34). A preferential tax treatment for SMEs vis-à-vis large firms can take the form of enhanced tax credit or allowance rates (e.g. Norway, Japan - volume-based R&D tax credit, Korea and United Kingdom - R&D Tax Allowance-SMEs). This preferential tax treatment for SMEs can create a gap between the implied tax subsidy rate estimates for SMEs and large firms.

Differences in implied marginal tax subsidy rates between the profit and loss-making scenarios arise as a result of national refund and carry-forward provisions. Such provisions are sometimes used to promote R&D in firms that may not otherwise use their credits or allowances. Such provisions can be exclusively available to or more generous for SMEs and young firms as opposed to large enterprises. This is the case for France as well as Australia and Canada. In countries where R&D tax incentives entail neither a carry-over nor refund option (Brazil, Japan and the Russian Federation), loss-making firms experience a full loss of tax benefits. In the Netherlands, tax offsets are redeemable against payroll taxes and disconnected from the corporate tax liability of the firm. The implied marginal R&D tax subsidy rates for profitable and loss-making firms thus coincide. Overall, there is large variation in R&D tax subsidy rates across countries.

3.2.3. Marginal vs. ex-post average R&D tax subsidy rates, 2016

A comparison of marginal R&D tax subsidy rates (1-*B-Index*) and ex-post average R&D tax subsidy rates (GTARD as a percentage of BERD) can shed light on the extent to which tax incentive design features influence the cost of government tax relief for business R&D. **Section 2.3** outlined how marginal and ex-post average tax subsidy rates relate to one another, including their conceptual differences. The current section illustrates graphically the relationship between the two subsidy rates and highlights the impact of some of the sources of divergence (**Section 2.3**).

One challenge arises in the aggregation of the four *B-Index* scenarios. In cases where there are preferential terms for SMEs, their *B-Index* would differ from that of large firms. To provide an informed comparison between the marginal and ex-post average implied subsidy rates, the share of SMEs in BERD is used to create a weighted average *B-Index* for the profitable case[22] whenever relevant data are available. Furthermore, to enable a like-by-like comparison, average subsidy rates are scaled by the net-of tax rate for large firms (1-CIT), mapping the normalisation undertaken in the *B-Index* estimation.

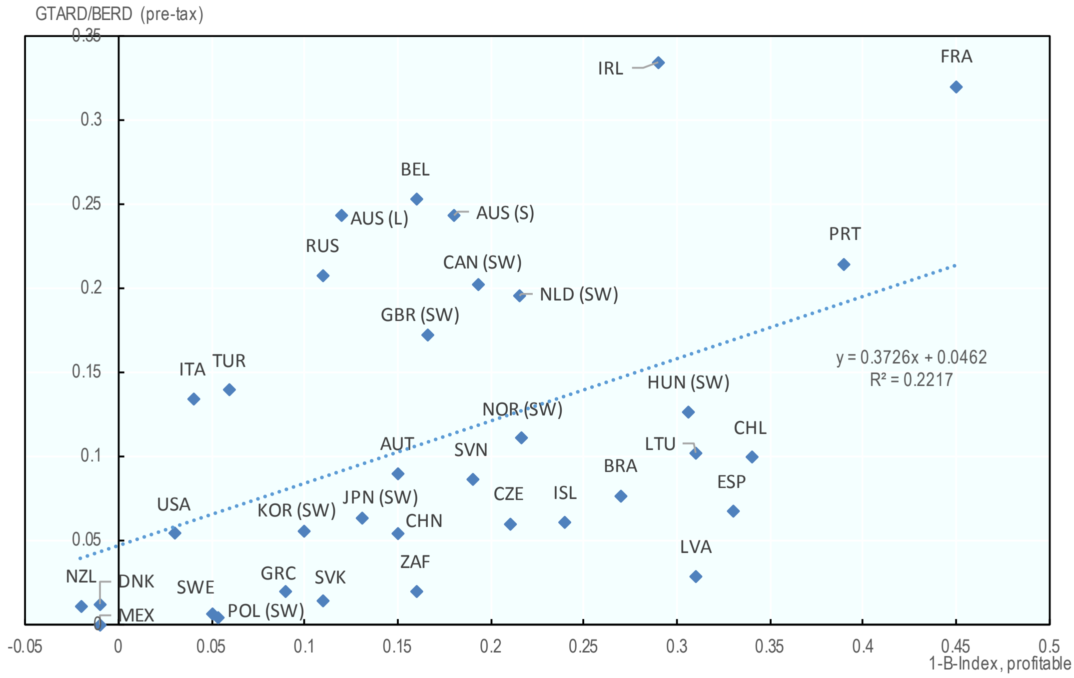
Figure 5 plots the ex-post average subsidy rate for 2016 (or closest year) and the implied subsidy rate (1-*B-Index*, profitable case), reporting size-weighted (SW) average *B-Index* estimates for profitable firms and separate estimates for profitable SMEs (S) and large (L) firms whenever aggregation is not possible.[23] There is a positive association between the two magnitudes. As expected, a higher implied marginal R&D subsidy rate seems to be closely associated with a higher ex-post average subsidy. This suggests that the cost of government tax relief for R&D is principally driven by the design of tax incentives.

As discussed in **Section 2.3,** the published time series of the *B-Index* does not account for the impact of ceilings and thresholds. Unweighted implied marginal R&D tax subsidy rates tend to overstate the generosity of tax incentives when such limitations are binding. In the case of France, for instance, the unweighted *B-Index* for a large profitable firm in 2016 equals 0.43 and the weighted one equals 0.32, the latter accounting for the threshold that applies to eligible R&D.

R&D tax incentives can also provide relief to extramural R&D. Since BERD only captures intramural R&D, the broader scope of GTARD with respect to BERD can cause average subsidies to be upward-biased. In cases where extramural R&D is eligible for relief, this will cause the cloud of points in **Figure 5** to move closer to the ‘x’ axis.[24]

Figure 5. Ex-post average vs. implied marginal R&D tax subsidy rates, 2016

GTARD/BERD (pre-tax) and 1-*B-Index* (profit scenario, weighted by SME share in BERD)



Note: The implied subsidy rate is weighted using the share of SMEs in BERD (SW). The share of SMEs in BERD in 2015 is used to weight the *B-Index* for Hungary, Netherlands, Norway and Poland in 2016. For Canada, the 2013 weight is used as an approximation. Weights were not available for Australia and therefore both implied subsidy rates for large (L) and small (S) are presented as an upper and lower bound.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

R&D tax benefits are also taxable in a number of cases (e.g. payroll tax incentives). If countries report gross of tax measures of GTARD, average R&D tax subsidy rates based on GTARD will overstate the true support and be out of sync relative to the marginal tax subsidy rates based on the *B-Index* which accounts for the taxability of R&D tax benefits. The *B-Index* calculation in turn excludes incentives related to personal income, value added, property taxes, as well as taxes on wealth and capital. Such incentives are captured by GTARD in only few cases (e.g. the Russian Federation).

A low uptake of the R&D tax incentive is the main substantive factor explaining why some countries offering high implied subsidy rates observe nevertheless a comparatively low average ex-post subsidy. A limited uptake of the R&D tax incentive can be related to design, implementation and enforcement rules that, for example, prevent the simultaneous use of other types of support (e.g. government grants); or risk and compliance costs that may arise if requirements are burdensome or generate uncertainty within firms with regard to the outcome of pre-approvals, the scope of auditing and potential disclosures. There may also be capacity constraints within firms or in the business advisory marketplace to facilitate the effective take up of available tax incentives.

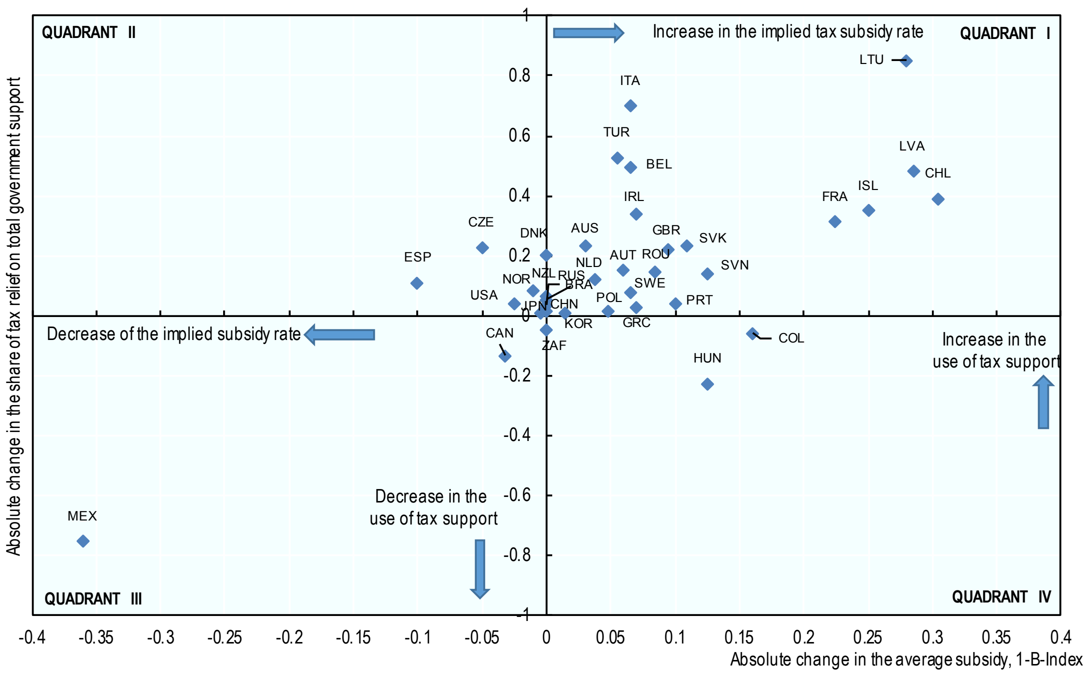
3.3. Trends in the relative and absolute magnitude of R&D tax subsidies

3.3.1. Changes in the policy mix and generosity of R&D tax incentives, 2006-16

With the increasing proliferation and generosity of R&D tax incentives across OECD countries and partner economies over the last decade, the R&D support policy mix has shifted towards a greater reliance on tax vis-à-vis direct support measures. At OECD level, tax support represents 46% of total government support in 2016, compared to 36% in 2006. At the EU level, the shift in the policy mix is even more pronounced with the share of tax support on total government support almost doubling in the course of 10 years (31% in 2006 to 57% in 2016).

In order to analyse cross-country trends in more detail, **Figure 6** illustrates changes in the R&D support policy mix across countries between 2006 and 2016.[25] It shows the absolute changes in the share of tax incentive support in total government support for business R&D (y-axis) and contrasts those with changes in the generosity of R&D tax incentives, as measured by the absolute changes in the implied marginal tax subsidy rate based on the average *B-Index* (x-axis) across the four firm size and profitability scenarios.

Figure 6. Policy mix and generosity of R&D tax support, OECD countries, 2006 vs 2016



Note: Estimates of the cost of tax support are unavailable for Israel. Countries with no R&D tax incentives in both periods are not included for visibility (Switzerland, Germany, Estonia, and Finland).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

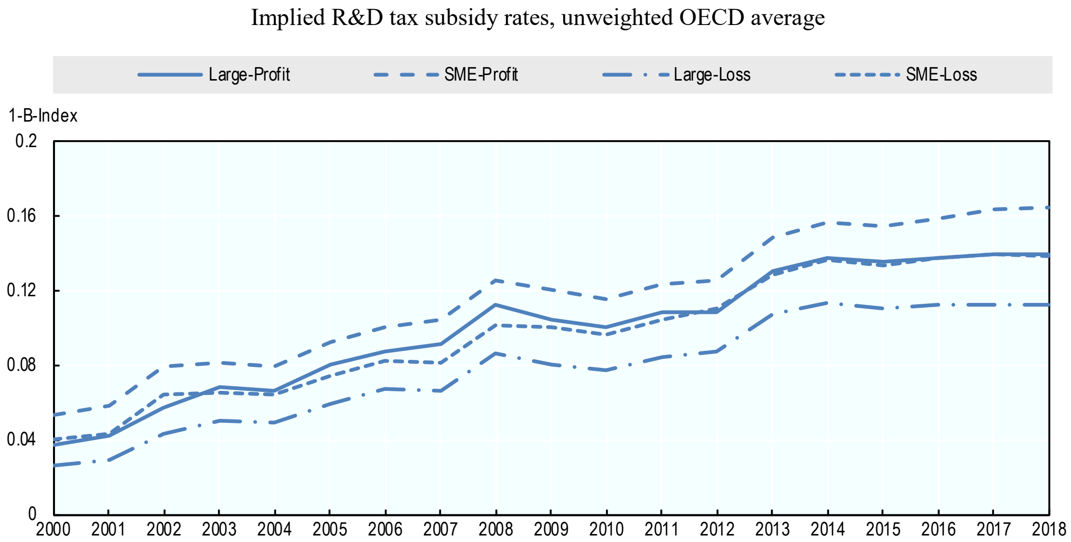
The interpretation of **Figure 6** is facilitated by dividing the graph into four quadrants. Countries located in the top quadrants I and II have increased the share of tax relief in total government support for R&D over time, the converse for those in quadrants III and IV. Countries placed in quadrants I and IV have increased the generosity of their tax relief provisions, the converse for those in quadrants II and III. Most countries lie within quadrant I. This implies that over time, R&D tax incentives have increased their relative importance (share) in governments' policy mix but also that governments have made tax relief provisions more generous over time.

However, this trend is far from uniform. For countries in quadrants III and IV (e.g. Hungary, Canada), a reduction in the share of tax support in total government support can be observed, i.e. a rebalancing towards direct support. The position of Mexico reflects the abolition of the R&D tax relief from 2007. Until the reintroduction of R&D tax incentives in 2017, support in those years for R&D was solely offered through direct funding.

3.3.2. Marginal and ex-post average R&D tax subsidy rates

Figure 7 displays the aggregate trends in implied marginal tax subsidy rates across OECD countries over the 2000-18 period. An analysis of aggregate trends sheds light on the overall developments in the generosity and uptake of R&D tax incentives over time.

Figure 7. Implied R&D tax subsidy rates: aggregate trends, 2000-2018, OECD countries



Note: Figures reflect the tax treatment of R&D expenditure for SMEs and large enterprises in OECD countries including those that do not offer tax incentive support for business R&D expenditure. Figures for Greece apply to the 2004-2017 period and for Turkey, figures refer to 2008-2018. Figures do not reflect preferential provisions for start-ups, young firms or a specific subset of SMEs (e.g. innovative SMEs).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

OECD implied R&D tax subsidy rates experienced a sustained growth over the first half of the 2000-2018 period, up until the onset of the global economic and financial crisis. The growth in subsidy rates resumed shortly afterwards. From 2014, implied tax subsidy rates remained stable with the exception of SMEs. Subsidy rates for profitable SMEs went from approximately 0.05 in 2000 to 0.16 in 2018 (0.04 to 0.14 for loss-making SMEs).

Throughout this time period, SMEs faced on average a higher marginal tax subsidy rate than large firms, both for profit-making and loss-making firms. It is worth noting that from 2009 onwards, the mean R&D tax subsidy rates for loss-making SMEs and large profitable firms coincide.[26]

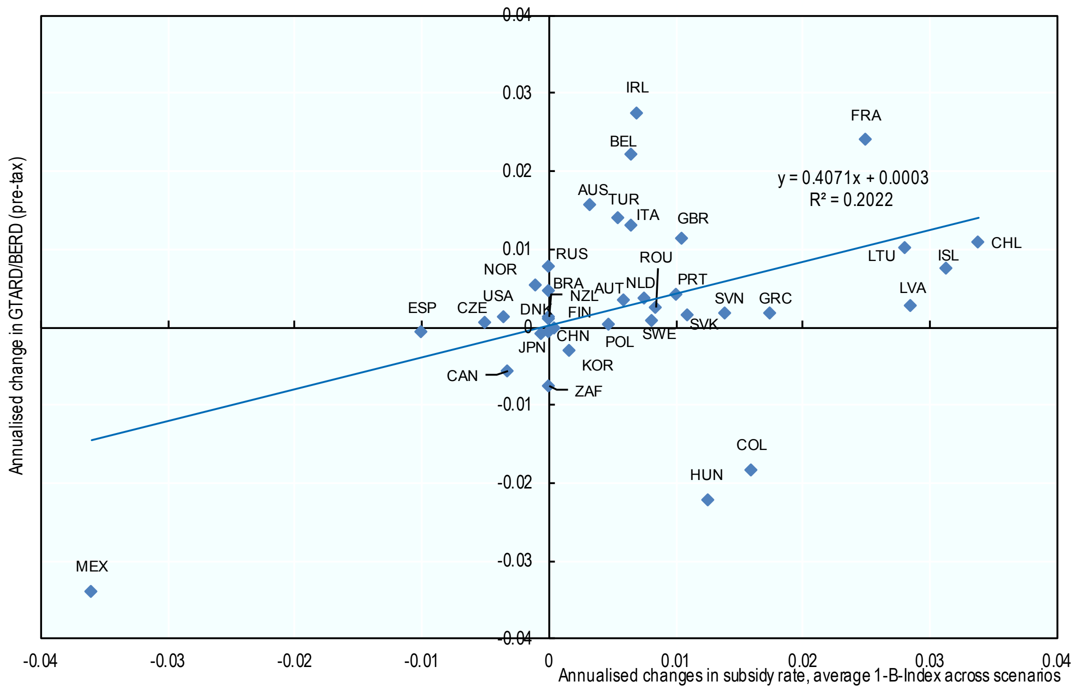
The evolution of R&D tax subsidy rates for large firms and SMEs at the 25th and 50th percentile (median) highlights the increasing adoption of R&D tax incentives by governments over time. As the majority of countries did not offer R&D tax relief until mid-

2000, negative and zero tax subsidy rates are observed at the OECD median in the early 2000s. With the increasing adoption of R&D tax relief provisions, the median and 25th percentile R&D tax subsidy rates turn positive in 2004 and 2015 respectively. The evolution of tax subsidy rates at the median and 75th percentile suggest in turn an increasing generosity of tax incentives over time, with a brief respite seemingly connected to the global financial crisis.

While implied marginal (1-*B-Index*) and ex-post average (GTARD as a percentage of BERD, pre-tax) R&D tax subsidy rates capture different constructs (see **Section 2.3**), it is instructive to understand their joint-evolution over time. **Figure 8** displays the annualised changes in marginal and average R&D tax subsidy rates in OECD countries and partner economies offering R&D tax incentives during the 2006-16 period. A positive relationship can be again identified between these two measures - changes in the implied marginal tax subsidy rates are positively associated with changes in the pre-tax GTARD-to-BERD ratio. Some outliers are observable. This may reflect idiosyncratic tax incentive design or implementation features that escape conventional modelling.

Figure 8. Annualised changes in ex-post and implied subsidy rates, 2000-16

OECD countries and partner economies with R&D tax support during 2000-16

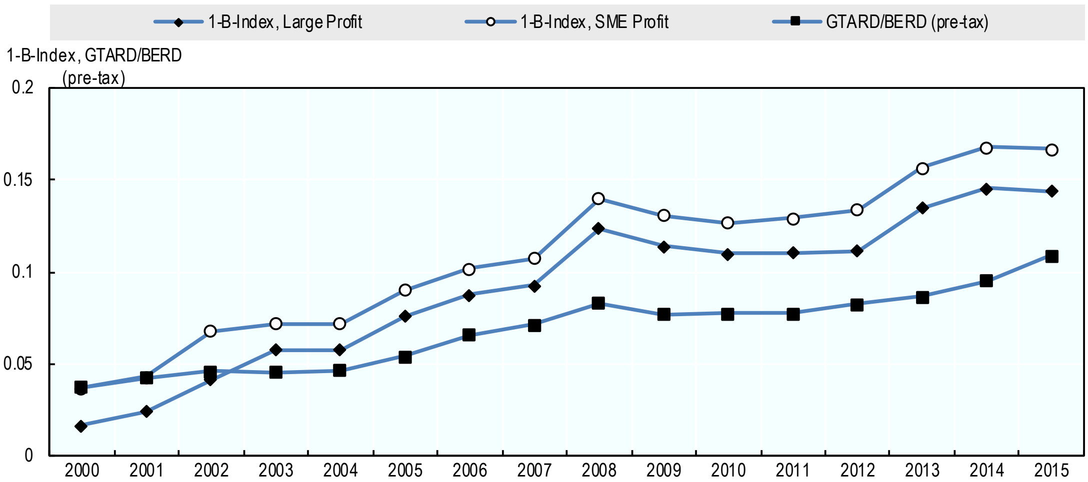


Note: Time-series estimates of the *B-Index* and/or the cost of tax support are not available for Argentina, Croatia, Israel and Malta. Figures do not reflect preferential provisions for start-ups, young firms or a specific subset of SMEs (e.g. innovative SMEs). Countries with no tax support during 2006-2016 include Bulgaria, Cyprus, Germany, Luxembourg and Switzerland.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

The time series data confirms the positive correlation between implied marginal R&D tax subsidy rates and ex-post average R&D tax subsidy rates, as measured by the pre-tax GTARD-to-BERD ratio (**Figure 9**). Over the 2000-16 period, marginal R&D tax subsidy rates (profit scenario) and GTARD-TO-BERD exhibit an increasing and similar trend for the OECD area. The (unweighted) average GTARD-to-BERD ratio falls below the (unweighted) ex-post average marginal rate of R&D tax subsidy based on the *B-Index* throughout this period. This may be related to the insufficient profitability and ability of firms to fully claim earned tax credits or the presence of thresholds and ceilings, creating a gap in average R&D tax subsidy rates and marginal tax subsidy rates based on headline tax credit (allowance) rates.

Figure 9. Ex-post average and marginal R&D tax subsidy rates, OECD countries, 2000-15

GTARD/BERD (pre-tax) and marginal R&D tax subsidy (1-*B-Index*), unweighted OECD average



Note: The graph contains estimates for 29 OECD countries. Spain is only included since 2002, United States and Iceland are included until 2013 and 2014 respectively. Time-series estimates of the *B-Index* and/or the cost of tax support are not available for Israel. Due to the lack of sufficient time series estimates of the cost of tax support for the 2000-15 period, Denmark, Greece, Hungary Korea and Turkey are excluded. Figures do not reflect preferential provisions for start-ups, young firms or a specific subset of SMEs (e.g. innovative SMEs).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

4. Analysis of the additionality of R&D tax support in OECD countries

As governments increasingly rely on R&D tax incentives to promote business R&D investment, policy makers expect this to result at least in additional R&D performance — often described as input additionality. Cross-country analysis of input additionality can provide useful insights into the overall effectiveness of R&D tax incentives across various countries. This macro-level view, which exploits the cross-country and temporal variation in their use, design and generosity, complements micro-level analyses that are typically limited to individual countries, but conversely yield relevant insights into firms' heterogeneity in the use and impact of tax incentives.

The effectiveness of R&D tax incentives in raising R&D investment can be gauged through econometric analysis that estimates the elasticity of business R&D to measures of tax relief for R&D as derived in the OECD database. The *OECD R&D Tax Incentives Database* contains two country-specific time-series relative to tax support: 1) the *B-Index* estimates for the 2000-18 period (by firm size and profitability scenario); 2) the estimates of government tax relief for R&D (GTARD) at central government level for 2000-16. These novel time-series indicators, exploited in the empirical analysis, facilitate a more comprehensive cross-country analysis of input additionality combining two different but complementary approaches to estimating the impact of R&D tax support.

As the tax component of the user cost of R&D, the *B-Index* allows for the estimation of R&D price elasticities which is the widely used approach to studying the effectiveness of R&D tax incentives at the macro level. The newly available GTARD time-series specifies the actual cost of tax support to the government. GTARD estimates facilitate a more direct estimation of the change in R&D expenditure induced by a change in government tax support for R&D, i.e. what is commonly referred to as 'bang for the buck' or BFTB.[27]

These two elasticities can be translated into incrementality ratios that inform the assessment of R&D input additionality. Estimates of input additionality indicate how much *additional* R&D expenditure one monetary unit of government subsidy induces. They provide the basis for a cost-benefit assessment of R&D support policies. However, cost-benefit analysis are broader in scope as they aim to capture the direct and indirect effects of policies, such as the cost of raising public funds and R&D spillover effects. It is important to note that even when incrementality ratios suggest that public funds partially crowd out private R&D spending, policies can still imply a positive value for money if private and public returns to R&D are sufficiently high.

4.1. Estimation sample

The study presented in this report investigates the impact of tax and direct support for business R&D in OECD countries over the 2000-16 period, using unbalanced panel data on business R&D investment and public support for R&D from the *OECD R&D Tax Incentives Database* and the *OECD MSTI database*:

- ***OECD RDTAX database* (2018/2):** *B-Index* (2000-18); GTARD (2000-16).
- ***OECD MSTI database* (2018/2):** Business-funded BERD, direct funding of BERD and GDP and economic deflators for the period 2000-16.

The analysis is confined to 21 OECD countries during the 2000-16 period: 19 countries that offered R&D tax incentives for five years or more between 2000 and 2016 (Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States) and 2 countries (Germany and Luxembourg) that provided no R&D tax support during those years[28]. The 5-year restriction aims to ensure a consistent basis for estimating the short and more long-term effects of R&D tax incentives. Temporary tax incentives (e.g. Finland 2013-14, New Zealand 2008) are likely to have a differential impact than permanent provisions, and there is typically a delay in the uptake of R&D tax incentives by firms (e.g. due to awareness) following their introduction.[29]

The resulting panel is unbalanced. Missing observations may occur due to the infrequent reporting of business-funded BERD and direct funding of BERD as well as due to incomplete GTARD time series data. These values are assumed to be missing completely at random and no imputation is made for them in the main specifications. As a robustness test, missing observations are imputed (direct funding and business-funded BERD) using adjacent year's averages whenever data are available for the year preceding and succeeding the year for which data are missing. Imputation allows for the sample of countries with

R&D tax incentives during the period of study to increase from 19 to 21 countries, with the additions of Austria[30] and the Netherlands.

Breaks in series due to statistical methodological changes are common, for example as the coverage of the survey, the method to select units or the data sources change. These changes are recorded in the RDS and MSTI databases for BERD and its components, business-funded BERD and direct funding. Breaks in series do not necessarily jeopardise the reliability of the time series but care needs to be exercised in the estimation to ensure an accurate interpretation of the economic phenomenon under investigation, especially if the methodological changes have to do with other changes induced by the policies under analysis. For example, in some instances, the coverage of business R&D surveys may change to reflect heightened awareness of small R&D performing firms not previously included in the sampling frame for R&D surveys. Two significant breaks in series in BERD and direct funding of BERD are identified and dealt with in the analysis: Portugal (2008) and the Netherlands (2011).[31] In order to account for these breaks, different levels are specified before and after the break, leaving out from the analysis the year in which the break occurs. This strategy allows creating separate means for the country (pre and post break) while not allowing observations differently measured to feed together into the estimation. However, due to insufficient number of observations in the post-break period (less than 5 observations), only the pre-break period for Portugal (prior to 2008) and Netherlands (prior to 2011) enter the analysis. [32]

Table 1 presents summary statistics for the key variables in the analysis, which covers 21 OECD countries over the 2000-16 period.[33] Variables are expressed in levels (constant PPP USD 2010, millions) and as a percentage of GDP. The *B-Index* ranges from a maximum of 1.04 (Germany, 2003) to 0.55 (Spain 2003-06, France) which is equivalent to an implied tax subsidy of 0.45 (1-*B-Index*). The median *B-Index* value is 0.87 implying a median R&D tax subsidy rate of 0.13 across the estimation sample and period.

Table 1. Summary statistics for the estimation sample

Group of 21 OECD countries with and without R&D tax incentives

Variable	Number of country*year observations	Mean	Median	Standard deviation	Minimum	Maximum
Constant USD 2010, millions						
BUSBERD	244	31,101	7,892	59,959	94	291,095
GTARD	233	1,443	439	2,212	0.00	10,667
R&D DirectFunding (DF)	242	2,528	581	6,547	20.57	40,231
B-Index	244	0.85	0.87	0.13	0.55	1.04
GDP	244	2,212,354	1,428,392	3,424,035	44347	16,972,346
As % GDP						
BUSBERD/GDP	244	1.02	0.77	0.68	0.10	3.16
GTARD/GDP	233	0.08	0.05	0.07	0.00	0.29
DF/GDP	242	0.08	0.07	0.05	0.00	0.28

Note: Instances with fewer than 244 observations are due to missing data for the relevant variables.
Source: OECD analysis on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

The GTARD time series contains more missing observations due to incomplete data on the cost of R&D tax support. GTARD as a percentage of GDP ranges from 0 (countries with no tax incentives) to 0.29% (France, 2015). Among those countries with tax support, the lowest value of GTARD amounts to less than 0.0001% of GDP (Belgium, 2005).

4.2. Methodology

This section presents the methodology used to estimate the link between business R&D and government support, based on an overview of the R&D investment models used in the literature. A summary of the findings in these studies is available in **Annex C**. The section concludes with an outline of the estimation methods used to translate the estimated elasticities into estimates of R&D input additionality.

4.2.1. Estimation methods

The estimation methodology is twofold. The first approach estimates the elasticity response of business R&D to its price, measured by the *B-Index*. The second approach estimates the elasticity of R&D to the *actual* amount of government tax relief for R&D (GTARD). Both types of estimates control for the amount of direct support provided by government (DF).

The link between BERD and the B-Index

The most common approach to study the impact of R&D incentives on business R&D investments exploits the policy-driven variation in the user cost of R&D. This approach follows the seminal work of Hall and Jorgenson (1969[9])[34] and develops a measure of the cost of performing R&D based on general tax system information combined with country-specific R&D tax incentive design information. To account for the persistency of R&D, a lag of business-funded BERD is typically added to the R&D investment model:

$$logBUSBERD_{it} = \alpha_0 + \alpha_1 logBUSBERD_{it-1} + \gamma_1 log\, \rho_{it} + \alpha_2 \Omega_{\mathrm{it}} + \varepsilon_{it}, \qquad (2)$$

where $BUSBERD_{it}$ represents business-performed R&D investment in country i at time t and $BUSBERD_{it-1}$ its lagged value. ρ_{it} represents the cost of performing R&D that is country and time specific. Ω_{it} is a vector of macroeconomic variables (e.g. a control for the level of output or value added), while ε_{it} is the error term. Variables enter the analysis in natural logs, so that γ_1 identifies the elasticity of business R&D to changes in its cost (proportional response).

The user cost of R&D consists of two components: an economic component that is affected by macroeconomic factors (sum of economic depreciation and discounting); and a tax component that conveys all the relevant information related to the tax system and R&D tax incentives. The tax component of the user cost is what has been commonly referred to in the literature as the *B-Index*, developed by Warda (2001[5]) and extended by OECD (2013[6]; 2018[7]) to capture differences in the tax treatment by firm size and profitability.

Bloom et al. (2002[10]) compute the user cost of R&D for a sample of 9 countries over the 1979-97 period in order to estimate the price elasticity of R&D. Other studies use solely the tax component of the user cost (Guellec and Van Pottelsberghe De La Potterie, 2003[11]; Thomson, 2017[12])[35] as a measure of the cost of performing R&D, i.e. $\rho_{it} \sim B - Index$ in (2). The adoption of the *B-Index* aims to avoid endogeneity issues that may arise from the economic component of the user cost.[36] [37] Since governments can support R&D through other direct instruments, the model in equation (2) can be expanded to incorporate an additional policy variable, yielding equation (3),

$$logBUSBERD_{it} = \alpha_0 + \alpha_1 logBUSBERD_{it-1} + \gamma_1 log\rho_{it} + \gamma_2 logDF_{it} + \alpha_2 \Omega_{it} + X\alpha_4 + \varepsilon_{it}, \quad (3)$$

where DF_{it} represents direct funding from the government to business R&D and X represents a vector of other relevant covariates that may influence business R&D expenditure (e.g. long-term interest rates, corporate income tax rates)[38]. Direct funding of BERD, reported by firms in national business R&D surveys is contemporaneous to R&D performance, so while firms may be aware of such funding in advance it is an element of current BERD by construction. In order to avoid the endogeneity of direct funding and BERD, the dependent variable is chosen to be business-funded BERD instead of BERD.[39] The coefficient γ_2 thus identifies the elasticity of business-performed R&D to changes in direct funding. This extended R&D investment model has also been adopted by (Falk, 2006[13]; Thomson and Jensen, 2013[14]; Montmartin and Herrera, 2015[15]).

The first part of this cross-country analysis estimates the R&D price elasticity using the *B-Index* (large firm, profitable scenario) as a measure of the user cost of R&D ($\rho_{it} \sim B - Index$) and the partial-adjustment model considered in equations (2) and (3). This model is standard in the literature in order to account for the persistency of business-performed R&D (Bloom, Griffith and Van Reenen, 2002[10]; Guellec and Van Pottelsberghe De La Potterie, 2003[11]; Thomson, 2017[12]).[40]

In this paper's empirical application, the *B-Index* for large profitable firms is chosen as the reference policy indicator in order to estimate the elasticity of business R&D to the price of R&D and degree of input additionality. Ideally, the regressions should adopt a suitable weighted average of the *B-Indices* applicable in the four reference scenarios (small profitable, large profitable, small loss-making, large loss-making). This is not yet possible because the relevant R&D weights cannot be calculated, in particular for loss making scenarios. The *B-Index* indicator for large profitable firms is used because this scenario appears to reflect the majority of R&D and, based on additional checks, this variable appears to be most closely correlated with GTARD. Future editions of the OECD database may contain a recommended average *B-Index* for the entire economy, drawing on ongoing microdata work within countries to derive valid weights.

Since the models can be augmented to capture the impact of other relevant covariates in explaining business R&D reflected in vectors Ω and X, the regressions include GDP as a control for the level of activity and market size. Given their persistent nature, BERD and GDP are potentially non-stationary, possibly integrated of first order—I(1). This may lead to a spurious correlation between the dependent and control variables. A test for unit roots in the residuals is performed in order to rule out this possibility. The residuals are likewise tested for serial correlation.[41] To correct for the endogeneity bias introduced by the lagged dependent variable, previous studies adopt alternative dynamic panel methods ranging from fixed-effects instrumental variables (IV) (Bloom, Griffith and Van Reenen, 2002[10]) to Kiviet's corrected least squares estimations (Kiviet, 1995[16]), and difference and system GMM estimations (Arellano and Bond, 1991[17]; Blundell and Bond, 1998[18]). While GMM estimators have become popular to address issues of short-panels and endogenous covariates, some challenges arise in their implementation.[42]

The estimation strategy adopted in the current paper follows Bloom et al. (2002[10]) by using a fixed-effects instrumental variable procedure, where the lagged dependent variable is treated as endogenous and instrumented using its second and third lag. Different specifications have been tested using GMM specifications but the proliferation in the instrument set (even after using the general tools of collapsing the instrument set) raised concerns over the adequacy of the technique in the context of this analysis.[43]

Direct funding is often considered to be exogenous at aggregate levels of data aggregation (e.g. country) –the amount of transfers and expenditure of the government is predetermined and budgeted in advance–before any expenditure takes place at the firm level (Guellec and Van Pottelsberghe De La Potterie, 2003[11]). However, governments may budget for R&D in anticipation of expected changes in R&D in the economy, for example to compensate for changes in business R&D investment intentions. Also, government R&D budgets and business R&D may respond to common economic shocks. Due to the unavailability of a fully satisfactory instrument to account for the potential endogeneity of direct funding, this variable is effectively treated as exogenous.[44] [45] For robustness, the model is augmented to include the impact of the long-term interest rate and the corporate income tax rate in explaining business R&D.

The link between BERD and GTARD

The second approach exploits for the first time the newly available time-series of GTARD. Business R&D investment is explained by the total amount of public support received by firms: indirectly through the tax system, i.e. the actual cost of tax support (GTARD) and directly through direct support (e.g. R&D grants and procurement).

Unlike the previous approach, R&D tax incentives are in this case not modelled using the theoretical measure of the user cost of R&D or its tax component (*B-Index*). The model proposed resembles the one applied by Dumont (2017[19]) at the micro level. The estimating equation takes the form of (4):

$$logBUSBERD_{it} = \beta_0 + \beta_1 logBUSBERD_{it-1} + \delta_1 logGTARD_{it} + \delta_2 logDF_{it} + \beta_2 logGDP_{it} + \varepsilon_{it}, \quad (4)$$

where $logBUSBERD_{it}$ represents the logarithm of business-funded BERD for country i at time t and $logBUSBERD_{it-1}$ its lag; public support to R&D is accounted for by the cost of tax support, $logGTARD_{it}$, and the amount of direct support, $logDF_{it}$ and ε_{it} is the error term. Direct funding of BERD and accrual-based GTARD[46] estimates are aligned with the year of R&D performance and are therefore considered as contemporaneous. As the size of the economy also seem to be correlated with BERD intensity, GDP is introduced as a control. All variables are expressed in natural logs and in constant PPP USD. δ_1 and δ_2 represent the short-run elasticities of the cost of tax support and direct funding respectively. Given the specification in logarithms, this model only considers countries that provide tax support for R&D during the 2000-16 period. [47]

Equation (4) is estimated using a fixed-effects instrumental variable procedure in order to address two potential sources of endogeneity in the estimation of (4): the lagged dependent variable and GTARD. The presence of the lagged dependent variable introduces endogeneity (known as the "Nickell bias") and is instrumented using its second and third lag. GTARD is related to the level of business R&D expenditure in the economy and business-funded BERD may partially include GTARD[48] in the sources of own funds reported by firms.

Moreover, there may be a certain degree of measurement error in GTARD due to the temporal misalignment of intramural R&D expenditure and estimates of the cost of tax support (see **Section 2.1**). This measurement error would attenuate its coefficient (Bound, Brown and Mathiowetz, 2001[20]). If this measurement error is not related to business-funded BERD; instrumental variables that are correlated with the instrument and uncorrelated with the measurement error will correctly identify the coefficient of interest.

In order to address the potential endogeneity of GTARD and its measurement error, the *B-Index* can act as a potentially valid instrumental variable.[49] As a synthetic measure of the design features and generosity of R&D tax incentives, it is not directly related to the level of R&D performance and the potential demand for the incentive in a country. The first-stage regression for GTARD resulting from an IV two-stage estimation of (4) is given by:

$$logGTARD_{it} = \lambda_0 + \lambda_1 logBindex_{it} + X\lambda_2 + Z\lambda_3 + \mathrm{u}_{it} \qquad (5)$$

where X is a vector of independent exogenous covariates and Z is a vector of instruments to address the endogeneity of the lagged dependent variable. In this case, the second and third lag of business-funded BERD are used as instruments.

The reduced-form equation of (4) [equation (6)], represents a regression of the dependent variable, $BUSBERD_t$, on the instrument set (in the place of the endogenous variables); and the rest of exogenous covariates. For this particular case, it is a regression of $BUSBERD_t$ on the *B-Index*; the second and third lags of business-funded R&D; and other exogenous covariates.

$$\begin{aligned} logBUSBERD_{it} = \alpha_0 + \alpha_1 \sum_{j=2}^{3} logBUSBERD_{i_{t-j}} + \alpha_2 logBindex_{it} \\ + \alpha_3 logDF_{it} + \alpha_4 logGDP_{it} + \varepsilon_{it}. \end{aligned} \qquad (6)$$

Previous studies estimating the effect of the user cost of R&D on business R&D, i.e. equations (2) and (3) (Bloom, Griffith and Van Reenen, 2002[10]; Guellec and Van Pottelsberghe De La Potterie, 2003[11]; Montmartin and Herrera, 2015[15]; Thomson, 2017[12]) effectively estimate the reduced form of equation (4) i.e. equation (6).[50] Residuals are tested for serial correlation and for unit roots to ensure their non-stationarity.

4.2.2. Deriving estimates of R&D input additionality

While the estimated elasticities of business-funded R&D with respect to the *B-Index* and GTARD give a positive indication of tax incentives' capacity to stimulate R&D spending, they do not directly measure input additionality, i.e. the extent to which R&D tax incentives are effective in generating additional R&D expenditure beyond the level that would have been observed in their absence (counterfactual). The R&D 'incrementality ratio' (RDIR), also referred to as R&D 'bang for the buck - BFTB'), provides such a measure. It specifies the change in R&D investment per dollar of foregone tax revenue. For direct funding of BERD, such a ratio can be similarly estimated, facilitating a comparison of the input additionality of different policy instruments that aim to support business R&D and innovation.

Incrementality ratios as measures of additionality

An important aspect to factor in when interpreting and comparing **additionality estimates** is whether those are reported in **net or gross terms**, i.e. include the amount of R&D subsidy. Tax subsidies feature at least partially in firm's own financing of BERD and direct funding of BERD is, by construction, one component of BERD. This study adopts business-funded BERD (sum of own and other business financing of BERD excluding governmentfinanced BERD), *BUSBERD*, instead of BERD as the dependent variable. This generates a *net* elasticity measure for direct support and a *gross* elasticity estimate for GTARD and the *B-Index* (**Section 4.2.1**).[51]

In order to derive comparable incrementality ratios across the two instruments of support, it is necessary to add back one unit of government support[52] to the net additionality measure for direct funding to derive comparable gross estimates. Since gross incrementality ratios contain the unit of government support provided, the benchmark for assessing input additionality is the unit of R&D subsidy contributed by government. **Table 2** provides a guide to the interpretation of gross incrementality ratios estimated for the *B-Index*, GTARD and direct funding.

Table 2. Interpretation of gross incrementality ratios

Gross incrementality ratios (IR) for government support for R&D

Value of the estimated R&D incrementality ratio (RDIR)	Effect of government support	Interpretation
RDIR>1	Net additionality of support	One monetary unit of government support translates into *more than* one unit of R&D investment by the beneficiary, i.e. generates additional R&D investment by business over and above the amount that is supported.
RDIR=1	Gross additionality with neutral financial effect	One unit of government support translates into one unit of R&D investment, i.e. it is equivalent to the alternative of government dedicating the resource to its conduct of R&D (e.g. by government research institutes).
0<RDIR<1	Gross additionality with partial crowding-out	One unit of government support translates into less than one unit of R&D investment by the beneficiary, i.e. government support partially crowds out business R&D. Businesses allocate part of the support to other activities.
RDIR<=0	No additionality Full crowding-out	One monetary unit of government support for R&D completely crowds out business R&D investment by the beneficiary, which directs other resources to non R&D activities. There is a full substitution effect.

The specification of the R&D investment model in this paper accounts for the persistency of business R&D through the inclusion of a lag for the dependent variable of business funded BERD. The presence of dynamics in the model can result in various types of dynamic effects from the short to the long run arising from either transitory or permanent changes in government support through tax incentives or other mechanisms. In this paper, no information is used about the anticipated duration of the support, although it is likely that policy reforms considered to be transitory will result in much lower responsiveness of investment by firms in the short term. By allowing for an underlying persistence of R&D expenditure, it is possible in principle to compute, in addition to short term response elasticities, what would be the cumulative response over time arising from changes in the policy variables. This study focuses on reporting on the implied short-run additionality of government support. Estimates of long-run effects can be highly sensitive to the dynamic specification of the model. The different way in which direct and tax support enter the model and interact with the dependent variable (net vs. gross), also renders the cumulative estimates for each variable not fully comparable. In addition to this, a proper analysis of long term effects needs to take into consideration the additional government support arising endogenously from firms' increased future levels of R&D performance, which requires a comparison of financial measures across different points in time.

Incrementality estimation methods

Different methodologies for measuring the input additionality of R&D tax incentives are used in the literature (Mohnen and Lokshin, 2010[21]). While a number of micro level studies (Poot, Hertog and Brouwer, 2003[22]; Dechezleprêtre et al., 2016[23]; Dumont, 2017[19]; Guceri and Liu, 2019[24]) compute input additionality estimates, macro-level studies tend to report user cost elasticities but do not derive an input additionality estimate as such. As Montmartin and Herrera (2015[15]) note, this is related to the hitherto lack of country-level time-series data on R&D tax support (GTARD). One exception is the cross-country study by Thomson (2017[12]) which estimates the elasticity of R&D investment with respect to its tax-driven price based on industry-level data covering a panel of 29 industries in 26 OECD counties over the years 1987 to 2006. Based on this elasticity he derives an analytical measure of R&D additionality.

This paper discusses two main methods of estimating the incrementality ratio in the context of cross-country studies and applies those, exploiting the results from the *B-Index* and GTARD regressions presented in this paper. The second method also facilitate estimates of the input additionality of direct funding.

Method 1: Analytical derivation based on the *B-Index* elasticity

The **first method** – akin to the approach adopted by Thomson (2017[12]) – uses the estimated expected change in business R&D expenditure as a response to a marginal change in the user cost of R&D (*B-Index*), assuming that *B-Index* can be interpreted as an average cost measure from which total tax support can be derived.

Based on equation (2), the estimated parameter γ_1 represents the expected percentage change in business-funded R&D ($BUSBERD$) resulting from a marginal percentage change in the *B-Index* (B), i.e. $\frac{dBUSBERD}{BUSBERD} = \gamma_1 \frac{dB}{B}$. The gross incrementality ratio (IR), i.e. marginal change in business R&D ($dBUSBERD$) resulting from a marginal change in R&D tax expenditure ($d\widehat{GTARD}$) can be derived as:

$$RDIR_1^{Gross,Tax} := \frac{dBUSBERD}{d\widehat{GTARD}} = \left(\frac{1}{1-\tau}\right) * \frac{\gamma_1}{-B+\gamma_1(1-B)}, \quad (7)$$

where B and τ are calibration values for the *B-Index* and corporate income tax rate (CIT) respectively. This method assumed that the cost of tax support is approximated by the product of the implied marginal R&D tax subsidy and business-funded BERD: $\widehat{GTARD} = (1-B) * (1-\tau) * BUSBERD$[53]. This effectively implies substituting the average tax subsidy rate with the marginal R&D tax subsidy (1-*B-Index*). As discussed in **Section 2.2**, these rates differ in the presence of caps or threshold among other limitations that escape modelling and that limit relief. Hence the need to flag this representation of GTARD as an approximation.[54] One of the advantages of this first method is the tractability of the derivation of the incrementality ratio, and the possibility to calculate this measure solely based on the *B-Index*. Since data on the cost of R&D tax support (GTARD) may not necessarily be available, this approach is useful when computing estimates of R&D input additionality.

Method 2: Computation based on actual government support

The **second method** estimates the marginal effect of an increase in GTARD from the elasticities of business-funded R&D to GTARD. The elasticities of BUSBERD to GTARD and direct funding—equation (4) —identify the percentage change in R&D resulting from a percentage change in government support for R&D. This elasticity can be translated into a measure of the marginal increase in R&D following an increase in government support for R&D. The marginal effect of R&D tax support, for instance, can be estimated by multiplying the corresponding elasticity, δ_1, with the ratio of BUSBERD to GTARD.

$$RDIR_2^{Gross,Tax} = \frac{dBUSBERD}{dGTARD} = \delta_1 \frac{BUSBERD}{GTARD} \tag{8}$$

This second approach has been adopted by Dumont (2017[19]) at the firm level. The size of this marginal effect (incrementality ratio) depends on the value of the BUSBERD-to-GTARD ratio. The unweighted mean BUSBERD to GTARD ratio is chosen to enter the calculation of the (gross) incrementality ratio. Estimates based on the weighted mean of this ratio are presented as part of a sensitivity analysis (**Table D.6**).

The marginal effect of direct support can similarly be estimated by multiplying the elasticity of BUSBERD to direct funding, δ_2 in equation (4), with the ratio of business funded BERD to Direct Funding. In the case of direct support, the incrementality ratio derived from the estimation of equation (4) is net of the contribution of the government.

$$RDIR_2^{Net,DF} = \frac{dBUSBERD}{dDF} = \delta_2 \frac{BUSBERD}{DF} \tag{9a}$$

As aforementioned, the net incrementality ratio for direct support can be converted into a gross estimate by adding back the one unit of government support. This ensures the comparability of the incrementality ratios presented for direct and tax support.

$$RDIR_2^{Gross,DF} = \frac{dBUSBERD}{dDF} = \delta_2 \frac{BUSBERD}{DF} + 1 \tag{9b}$$

Section 0 reports the incrementality ratios for both policy variables in gross terms.

4.3. Results

4.3.1. Estimates of R&D elasticity to government support

The empirical strategy adopts two approaches to empirically analyse the link between business-funded BERD and government support (**Section 4.2**). The results from the *B-Index* regressions indicate the extent to which business-funded R&D expenditure is responsive to changes in the notional cost of performing R&D, measured by the *B-Index*, the tax component of the user cost of R&D. The results from the GTARD regressions allow for a more direct estimation of the additional R&D investment induced by an extra monetary unit of R&D tax relief, using the OECD GTARD estimates. This type of cross-country analysis applies an estimation approach previously confined to country-specific, micro level studies (Dumont, 2017[19]) and implements it for the first time in the context of a cross-country analysis.

The link between BERD and the B-Index

Analysing the core sample of nine OECD countries investigated in the seminal paper by Bloom et al. (2002[10])[55], the static version of the R&D investment model in **Table 3** – column (1) – yields a statistically significant negative R&D price elasticity to the *B-Index* as a measure of the user cost of R&D of -0.13. Introducing the dynamic structure to account for the persistency of R&D through a one year-lag of the dependent variable –column (2), the coefficient of the *B-Index* remains statistically significant and suggests a similar short-run elasticity of -0.14. Column (3), which addresses the endogeneity of the lagged dependent variable by instrumenting it with its second and third lag[56], is the preferred specification. The IV estimation yields a short-run elasticity of -0.14 of business-funded BERD with respect to the *B-Index*.

Table 3. Estimates of the effect of policy changes in the cost of R&D, 2000-16

Regression of log *Business-funded BERD* on log *B-Index*

Country-set	Same countries as in Bloom et al. (2002)			Extended group of OECD countries					
				with R&D tax incentives			with and without R&D tax incentives		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Method	FE	FE	FE-IV	FE	FE	FE-IV	FE	FE	FE-IV
	Static	Dynamic	IV	Static	Dynamic	IV	Static	Dynamic	IV
Dependent variable:	logBUSBERD t			logBUSBERD t			logBUSBERD t		
log BUSBERD t-1		0.902***	0.870***		0.883***	0.870***		0.768***	0.839***
		(0.0432)	(0.0472)		(0.0320)	(0.0379)		(0.0750)	(0.0411)
log *B-Index* t	-0.126*	-0.138***	-0.137***	-0.474***	-0.104*	-0.110*	-0.476***	-0.152**	-0.122**
	(0.0753)	(0.0374)	(0.0403)	(0.121)	(0.0602)	(0.0636)	(0.120)	(0.0680)	(0.0617)
log GDP t	-0.108	-0.0886	-0.0893	0.604**	0.0259	0.0350	0.613**	0.121	0.0755
	(0.317)	(0.106)	(0.116)	(0.239)	(0.0907)	(0.0954)	(0.240)	(0.116)	(0.0978)
Observations	120	120	120	228	228	228	244	244	244
Countries	9	9	9	19	19	19	21	21	21
Kleibergen-Paap Wald F			176.62			274.84			249.40
Anderson Rubin Chi			139.12			303.40			300.18
(p-value)			(0.00)			(0.00)			(0.00)
Underidentification			24.08			65.95			67.61
(p-value)			(0.00)			(0.00)			(0.00)
Hansen J			4.53			0.02			1.84
(p-value)			(0.03)			(0.89)			(0.18)

Note: All regressions contain country and year fixed effects. Missing values are not imputed. Estimation (1)-(3) include the same set of countries as Bloom et al. (2002): Australia, Canada, Germany, Spain, France, United Kingdom, Italy, Japan and USA. OECD in (4)-(6) include those that have R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. Estimations (7)-(9) also incorporate Germany and Luxembourg. In (3), (6) and (9) the lag of business-funded BERD is treated as endogenous and instrumented using the second and third lag of business-funded BERD. Standard errors in parenthesis are robust to heteroskedasticity. The samples used for the static [(1), (4) and (7)] and dynamic non-IV specification [(2), (5) and (8)] are restricted to match the same sample used in the IV specification [(3), (6) and (9)]. Results of the static and dynamic specifications are robust to the inclusion of the broader sample for which data are available. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019

Extending the analysis to a broader set of 19 OECD countries which offer R&D tax incentives for a period of 5 years or more during the 2000-16 period, the static specification – column (4) – yields a statistically significant *B-Index* coefficient that implies an R&D price elasticity of around -0.47. The incorporation of the dynamic term – column (5) – brings down the R&D price elasticity to -0.10. Column (6), the preferred IV specification, yields a short-run elasticity of the *B-Index* of around -0.11, which translates into a long-run elasticity of -0.84. These results are overall close to those estimated by Bloom et al. (2002[10]) and are comparable with those that are based on an extended sample including two countries with available data but no R&D tax incentives(Germany and Luxembourg) —columns(7) to (9). [57] [58]

Changes in the policy variable might exert differential impacts in business R&D depending on the size of the market and the economy. The analysis in this paper assigns equal weight to all observations regardless of the size of a country. Further robustness checks available in the Annex section (**Table D.3**) provide comparable results where observations are weighted on the basis of GDP. Overall, results tend to be similar in the weighted and unweighted specifications, with a slight tendency for the weighted results to accentuate the impacts identified for the policy variables, suggesting that impacts may be larger for larger economies.

Equation (3) highlighted the possibility of extending the model to include other relevant time-varying covariates that may also contribute to explain R&D investment (X). Extended specifications are available in **Annex D (Table D.4**), including the real long-term interest rate (OECD, 2019[25])[59] and the statutory corporate income tax (CIT) rate (OECD, 2018[26]; OECD, 2018[27]) as additional control variables. Although CIT rates are factored in the calculation of the cost of performing R&D (*B-Index*), their inclusion as a standalone variable aims to account for the possibility that a lower rate of tax may encourage higher R&D investment regardless of the level of tax subsidy. None of these two variables appear to have a statistically significant effect and the *B-Index* results are robust to their inclusion, suggesting that the tax subsidy is a genuine driver of investment decisions. While the lack of direct impacts from general tax rates and rates of return may sound paradoxical, this may be due to the fact that a substantial amount of R&D performance is accounted for by global companies which can locate their profits and sources of finance across different jurisdictions, lowering their effective tax rates. This can explain why their local investment decisions may not appear to be directly influenced by such domestic variables that do not fully capture their global activities.

A common question for policy makers is how direct and tax support for business R&D compare in terms of effectiveness. Extending the specification to include direct funding of BERD does not appear to correlate in a significant fashion with the measure of business-funded R&D (**Table 4**), from which the government support has already been netted out. Direct support would therefore appear to be additional on a gross, but not on a net basis, increasing business R&D by the same amount as the support received (neutral effect), but not inducing additional investment by firms through their own resources. The inclusion of this measure of support has no impact on the estimated elasticity of business-funded R&D in the baseline sample of 9 countries, but it does appear to attenuate it in the larger sample of 19 OECD countries, which includes smaller economies. The infrequent reporting of direct funding causes, however, gaps in the data that are accentuated in specifications using lagged terms, as in this paper. This leads to missing observations that can affect the precision of the estimates. This attenuation on the *B-Index* coefficient when controlling for direct support in the larger 19 OECD sample disappears if the regressions are estimated in the imputed dataset[60]. This specification uses measures of direct and tax support, i.e. *B-Index*, that are conceptually different, not allowing for a like-for-like comparison between the two policy measures. A full analysis of comparative additionality considering both direct funding and tax support will be provided in **Section 0** after having examined the elasticity of business-funded R&D to actual financial measures of tax support (GTARD) and direct funding.

Unsurprisingly, the results from the *B-Index* regressions confirm those found in the literature (**Table C.1**), set within a range of -0.14 to -0.28. For instance, Falk (2006[13]) estimates a short-run elasticity of -0.24. Studies vary in terms of country (industry) and time coverage, methods of estimation, use of control variables as well as the scaling of both dependent and covariates (**Table C.1)** for a schematic overview.

Table 4. Estimates of the effect of tax subsidies and direct funding on business-funded BERD

Regression of log Business-funded BERD on the *B-Index* and government direct support

Country-set	**Same countries as in Bloom et al. (2002)**		**Group of OECD countries with R&D tax incentives**	
	(1)	(2)	(3)	(4)
Method	FE	FE-IV	FE	FE-IV
	Dynamic	IV	Dynamic	IV
Dependent variable:	logBUSBERDt		logBUSBERDt	
Log BUSBERD t-1	0.900***	0.863***	0.890***	0.876***
	(0.0450)	(0.0464)	(0.0334)	(0.0398)
Log *B-Index* t	-0.136***	-0.131***	-0.0956	-0.102
	(0.0383)	(0.0384)	(0.0623)	(0.0640)
Log Direct GovFunding t	-0.00271	-0.00895	-0.00956	-0.00815
	(0.0207)	(0.0212)	(0.0143)	(0.0148)
Log GDP t	-0.0821	-0.0679	0.0385	0.0450
	(0.110)	(0.110)	(0.0939)	(0.0943)
Observations	120	120	228	228
Countries	9	9	19	19
Kleibergen-Paap Wald F		138.21		310.18
Anderson Rubin Chi		109.93		285.71
(p-value)		(0.00)		(0.00)
Underidentification		28.11		54.69
(p-value)		(0.00)		(0.00)
Hansen J		4.86		0.02
(p-value)		(0.03)		(0.9)

Note: All regressions contain country and year fixed effects. Missing values are not imputed. Estimation (1)-(2) include the same set of countries as Bloom et al. (2002): Australia, Canada, Germany, Spain, France, United Kingdom, Italy, Japan and USA. OECD in (3)-(4) include those that have R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. In (2) and (4) the lag of business-funded BERD is treated as endogenous and instrumented using the second and third lag of business-funded BERD. Standard errors in parenthesis are robust to heteroscedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax March 2019.

The link between BERD and GTARD

The availability of longitudinal data on GTARD for a group of countries enables, for the first time, the estimation of the elasticity of aggregate business-funded BERD with respect to the actual cost of tax incentives reported by governments. This is important because marginal and average tax subsidies generally differ. Marginal tax subsidies may also differ across companies within a country. The estimation of equation (4) does not rely on a theoretical measure of R&D tax subsidy but on the link between the actual support received by firms and the R&D investment in the economy. This also facilitates a more like-for-like estimation of the impact of direct and tax support for business R&D, as both measures reflect the actual amount of support provided to firms.

Table 5 presents the results from the regressions of business R&D on GTARD. This analysis is based on 19 OECD countries where R&D tax incentives were in place for at least five years during 2000-16. Because observations where countries do not offer R&D tax support (GTARD equals zero) do not enter the estimation in the log-based specification, the results identify "effects" of changes at the intensive margin in the amount of tax support, and exclude potential information based on the extensive margin when R&D tax incentives are adopted or dropped altogether.

Table 5. Estimates of impact of public support on business R&D investment, 2000-16

Estimates based on direct measurement of cost of tax support

Country-set	Group of OECD countries with R&D tax incentives					
	(1)	(2)	(3)	(3a)	(3b)	(3c)
Method	FE	FE-IV		FE-IV		
	Static	IV1	IV2	First	First	Reduced-form
Dependent variable:	logBUSBERDt	logBUSBERDt	logBUSBERDt	logBUSBERD t-1	logGTARD t	logBUSBERD t
logBUSBERD t-1		0.829***	0.822***			
		(0.0382)	(0.0387)			
logGTARD t	**0.0465*****	**0.0235*****	**0.0423*****			
	(0.0154)	(0.00474)	(0.0159)			
logDirectGovFunding t	**0.135*****	0.00498	0.00930	0.0127	**-0.242***	0.00947
	(0.0306)	(0.0143)	(0.0145)	(0.0165)	(0.137)	(0.0221)
logGDPt	0.308	0.0324	0.0180	-0.0420	1.086	0.0297
	(0.244)	(0.104)	(0.109)	(0.114)	(0.878)	(0.153)
log*B-Index* t				-0.177***	**-2.954*****	**-0.267*****
				(0.0497)	(0.464)	(0.0610)
logBUSBERD t-2				0.782***	1.122*	0.698***
				(0.0923)	(0.642)	(0.123)
logBUSBERD t-3				0.0444	-1.037*	-0.0153
				(0.0880)	(0.601)	(0.129)
Observations	202	202	202	202	202	202
Countries	19	19	19	19	19	19
Kleibergen-Paap Wald F		252.05	14.74			
Anderson Rubin Chi		245.34	257.32			
(p-value)		(0.00)	(0.00)			
Underidentification		46.46	22.67			
(p-value)		(0.00)	(0.00)			
Hansen J		0.13	0.01			
(p-value)		(0.71)	(0.93)			

Note: All regressions contain country and year fixed effects. Estimation (1)-(3) include OECD countries that have R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. Missing values are not imputed. Controls for structural breaks in Portugal (2008). Estimation (2) treats business-funded BERD as endogenous and is instrumented using the second and third lag of business-funded BERD. Estimation (3) also controls for the endogeneity of GTARD using the *B-Index* as an instrument. Standard errors in parenthesis are robust to heteroscedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

In the static specification – column 1 – both GTARD and direct funding are positively related to business-funded BERD. Once the lagged dependent variable is introduced – column 2 –the coefficients of both policy instruments drop in size and it is not possible to reject the hypothesis that direct funding has no effect on business-funded BERD (over and above the direct funding that is by construction included in total BERD). This result again suggests that one unit of direct funding translates into one unit of business-funded BERD but no additional R&D funded on the firm's own resources. The elasticity of business funded to GTARD is estimated at 0.02. The implementation of equation (4), addressing not only the endogeneity of the lagged dependent but also the potential endogeneity and measurement error present in GTARD – column 3 – uses the *B-Index* as an instrument to predict GTARD. In this case, the GTARD elasticity of GTARD is estimated at 0.04. Instrumenting using the *B-Index* appears to correct in part the attenuation measurement bias of GTARD (see **Section 2.1** and **4.2**).[61] In line with the econometrics literature[62], this estimator possibly identifies the effect of tax expenditures on R&D for a subset of countries where the introduction of more generous features induces additional, contemporary, take up of tax support by firms. This is more likely to be the case in countries where there is greater certainty among companies and no other constraints apply.

The coefficient of government direct funding of BERD is not significantly different from zero in any of the dynamic specifications presented for business-funded BERD. The elasticities for direct support, unlike for GTARD, represent net rather than gross elasticities. The results therefore suggest that, on average, direct funding has a neutral effect, i.e. while it may not induce additional R&D it also does not displace business-funded BERD. Previous studies often found it difficult to identify a clear-cut, significant effect of government subsidies on business-funded BERD at the aggregate level (Falk, 2006[13]; Wolff and Reinthaler, 2008[28]; Montmartin, 2013[29]). Guellec and Van Pottelsberghe De La Potterie (2003[11]) find a positive effect of direct funding with an elasticity of 0.08. Montmartin and Herrera (2015[15]) report a negative effect between direct support and R&D.

Several factors may explain the mixed outcome, such as potential endogeneity as well as restrictions on the combined use of tax relief and direct funding in countries (OECD, 2018[7]) and the length of the observation period. It is possible to note in column (3b) that GTARD and Direct Funding are negatively correlated with each other after accounting for other factors. This might confirm the view that governments tend to substitute one form of support for the other, thus making it difficult to identify the separate impacts of support provided through either instrument. In addition to this, it is likely that the impact of direct support programmes, designed and implemented in very heterogeneous ways across countries, is consistent with a wide range of potential impacts on R&D performance. This is appreciable in the much larger standard error found for direct support estimates.

The results for GTARD and direct funding are robust to the restriction of the analysis to countries with permanent provision of R&D tax support throughout 2000-16 i.e. results are not driven by countries introducing R&D tax incentives for the first time (**Table D.2**). **Table D.5** reproduces the analysis in **Table 5** to the sample where missing observations, due mostly to infrequent reporting, are imputed. The imputation of missing observations, which allows a larger sample size and permits the extension of the analysis to Austria and the Netherlands, identifies a positive and statistically significant effect of direct support on business R&D, pointing at additionality of the latter (over and above the direct support included in business R&D).

Business investment and government support for R&D

A final set of checks is implemented by assessing to what extent the measures of government support for R&D (direct or via tax incentives) help explain different measures of business investment. The empirical question of interest is whether the R&D policy support variables appear to have a more visible effect on the specific investment categories that are entitled to benefit from support compared to other asset categories that are not a priori affected by such policy decisions. Indirect effects may arise as a result of possible substitution or complementarity effects, or as a result of common factors underpinning general business investment decisions and policy choices. This is explored by using data from OECD National Accounts statistics and estimating investment equations for different capital formation categories. [63]

Following the recommendation in the 2008 System of National Accounts recognising R&D as capital formation (United Nations et al., 2009[30]), general capital formation statistics incorporate R&D among the broader range of so-called Intellectual Property Products (IPP), alongside investment in other assets typically described as tangible, such as land and buildings, and machinery and equipment. Estimates of R&D capital formation are typically based on data collected under the guidance of the Frascati Manual and then adjusted to meet SNA requirements (Ker and Galindo-Rueda, 2017[31]). Since data at this level are not yet systematically reported to the OECD, the comparisons with R&D are based on the reference variable of business funded R&D performed by business, using total Gross Fixed Capital Formation (GFCF) for the industries that most closely match the economic activities where the business sector is dominant[64] (in the absence of standalone data for the corporate sector) and the IPP investment sub-aggregate (which in addition to R&D also includes software and databases, mineral exploration and copyrighted originals). Two specifications for the investment equations are considered: one based on the *B-Index* and the other based on the two measures of government support—direct and tax (GTARD). In both cases the estimation uses a simple country and year fixed-effects regression model.

The results in **Table 6** show that the general business investment equation yields fairly standard results with no visible effect of public support for R&D on the overall measure of capital formation, of which R&D is a relatively small part. Although not significantly different from zero, direct government funding for R&D appears to be slightly negatively correlated with overall investment, which may be due to government decisions to provide this type of discretionary support to industry at times when investment is receding, for example during the latest global financial crisis. The high coefficient on GDP suggests that there is a very high elasticity with respect to total GDP, i.e. pro-cyclicality, also indicating a need to instrument this endogenous variable and, in general, the need for a more sophisticated econometric model that accounts for the persistency of the variables studied and their potential endogeneity. Country-level corporate income tax (CIT) rates do not appear to have an effect on any of the selected measures of investment, whereas long term interest rates (Real LIR) seem to have a negative effect on total investment but not on IPPs and R&D. With the fragmentation of global value chains due to globalisation, R&D activities have also become more fragmented (Galindo-Rueda et al., 2018[32]). R&D in particular tends to be highly concentrated among large companies who often operate in a global scale. This may explain why reference domestic interest and CIT rates do not appear to be the relevant measure of reference.

The main purpose of **Table 6** is to indicate the variation of the effect the R&D support policy variables depending on the relatedness of the investment variable to the measure of GDP. The *B-Index* appears to have no effect on IPP capital formation, whereas GTARD and direct support from government do both appear to be related, with a slightly higher effect for the latter. The results suggest that public support induces greater values of IPP investment through their impact on business funded BERD, and that the policy variables are not picking up other unmeasured effects other than, a small hint that direct support might be at times compensating for declining business investment. Estimates of R&D input additionality of government support

Table 6. General business investment and government support for business R&D

Business sector gross-fixed capital formation (GFCF), by type of asset

	Sample of OECD countries with R&D tax incentives					
	(1)	(2)	(3)	(1')	(2')	(3')
Dependent variable :	log GFCFt	log GFCF IPPt	log BUSBERDt	log GFCFt	log GFCF IPPt	logBUSBERDt
log *B-Index* t	**0.014**	**-0.067**	**-0.269***			
	(0.047)	(0.104)	(0.105)			
log GTARD t				**0.015**	**0.0453**	**0.0490****
				(0.011)	(0.0243)	(0.016)
log Direct GovFunding t				**-0.020**	**0.083****	**0.106*****
				(0.014)	(0.025)	(0.027)
log GDP t	1.829***	2.371***	0.365	1.997***	2.099***	0.310
	(0.149)	(0.540)	(0.194)	(0.178)	(0.601)	(0.250)
CIT t	0.350	0.807	0.391	-0.213	1.628***	0.778
	(0.261)	(0.562)	(0.452)	(0.272)	(0.429)	(0.413)
Real LIR t	-0.025***	0.027***	0.033***	-0.025***	0.025**	0.026***
	(0.005)	(0.008)	(0.007)	(0.005)	(0.009)	(0.007)
Observations	256	256	256	220	220	220
Countries	17	17	17	17	17	17

Note: All regressions contain country and year fixed effects. Missing values are not imputed. Real long-term interest rates (LIR) are calculated as difference between nominal 10-year benchmark government bond yields (OECD, 2019[25]) and contemporary year-on year core inflation rates. Core inflation excludes prices of food and energy. Estimation (1)-(5) include OECD countries with R&D tax incentives in place for at least 5 years and for which relevant data are available: Australia, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, the United Kingdom and the United States. Data on GFCF by type of asset are not available for Belgium and Turkey. Long-term interest rates are not available for Turkey. The analysis can be extended to countries without R&D tax support during 2000-16 (Germany, Luxembourg) – results are robust to this extension. Standard errors in parenthesis are robust to heteroscedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019 and Annual National Accounts Database, www.oecd.org/std/na, July 2019.

The regressions of business funded BERD on the *B-Index*, a proxy measure for the user cost of R&D, presented in the previous section yield an R&D price elasticity of around -0.12 in the short run. This suggests that business R&D investment reacts positively to reductions in the user cost of R&D via tax subsidies. Regressions of business-funded R&D on GTARD, a measure of the actual cost of tax support at central government level, have likewise shown that tax incentives affect business R&D positively. The elasticity of business funded BERD with respect to GTARD has been found to be between 0.02 and 0.04.

Based on these elasticities, the R&D incrementality ratio estimates for the *B-Index* and GTARD in **Table 7** provide novel cross-country evidence on the level of input additionality induced by R&D tax incentives. The RDIRs and their standard errors[65] for the R&D tax support and direct funding variables have been estimated based on the methods discussed in **Section 4.2**. Estimates are calibrated at the unweighted sample mean. R&D incrementality ratios are reported in gross terms, i.e. do not exclude the unit of government support from the reported R&D. Therefore, this one unit of government support represents the benchmark for assessing additionality – see **Table 2** for a guide to the interpretation of incrementality ratios.

Table 7. Estimated R&D incrementality ratios (RDIRs) for tax and direct support

Measures of gross additionality of public support

	Method 1 **Estimates based on the implied cost and impact of tax subsidy rates**		**Method 2** **Estimates based on direct measurement of cost of tax support and impact**	
	(1)	(2)	(3)	(4)
Underlying elasticities	**Table 3 – (6)**	**Table 4 – (4)**	**Table 5 – (2)**	**Table 5 – (3)**
Method (Instrumented variables)	IV (BUSBERD - dynamics)	IV (BUSBERD - dynamics)	IV (BUSBERD - dynamics)	IV (BUSBERD dynamics, GTARD instrumented by *B-Index*)
Gross R&D incrementality ratio for R&D tax support (Additionality benchmark=1)				
Tax support	*B-Index*	*B-Index*	GTARD	GTARD
RDIR estimate	**0.177**	**0.165**	**0.873**	**1.572**
Standard error	0.100	0.101	0.176	0.592
Gross R&D incrementality ratio for government direct funding (Additionality benchmark=1)				
Direct Govt Support	-	Direct Funding	Direct Funding	Direct Funding
RDIR estimate		**0.847**	**1.094**	**1.175**
Standard error		0.279	0.269	0.273

Note: Estimates refer to the tables in **Section 4.3** and **Annex D**. Standard errors for the RDIR ratios are computed using the delta-method. The calibration of the RDIRs is reported at the unweighted sample average: 0.838 for the *B-Index*, 0.275 for the statutory CIT rate, 37.19 for the ratio of business-BERD to GTARD and 18 for the ratio of BUSBERD to Direct Government Funding. Short-run elasticities are reported in the corresponding tables referenced in the heading. For further details and results for alternative specifications, please consult Annex **Table D.6**.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

The gross incrementality ratio estimated based on based on the *B-Index* (column 1 in **Table 7**) suggests that a one unit increase in R&D tax relief by governments translates on average into an increase in business R&D expenditure of 0.18, i.e. one unit of tax support generates significantly less than 1 unit of business R&D investment in the short-term. This estimate is robust to accounting for the separate role of direct support (0.17 in column 2), although statistically imprecise. The R&D tax support incrementality ratios based on the direct measurement of the cost of tax support and its impact (method 2, columns 3-4) are generally higher than those obtained for the indirect method.

Using the entry level specification (column 3) which accounts for the persistence in R&D intensity through an IV approach, the RDIR is estimated at 0.87, four times larger than using method 1. On this basis, the results indicate that tax incentive might be much closer to a neutrality scenario, with tax support being almost as effective in generating R&D investment as governments deciding to use the funds to carry out R&D within its own labs (i.e. there is almost a one-to-one ratio. One unit granted to firms as a direct subsidy translates into almost one unit of R&D investment).

For the calculation of the RDIR, method 1 attempts to approximate changes in the cost of tax support with changes in the *B-Index* indicator, which is based on assumptions to link a forward-looking rate such as the *B-Index* to the actual tax cost to the government. As previously noted, the country-level 1-*B-Index* indicator for large profitable firms used in the analysis is also an imperfect proxy for the marginal tax subsidy rate, not capturing the combined effects of ceilings and thresholds, preferential provisions for SMEs and different provisions for loss-making firms. Method 2 allows a more direct estimation of the average cost of tax support as well as use elasticities that are identified by changes in such costs. However, the estimation using GTARD is also subject to endogeneity because of the influence of business R&D plans and measurement error because reported tax support is often "out of sync" with current R&D expenditures (**Section 3.2.3**). For this reason, a variation of Method 2 instruments the value of the cost of tax support through the *B-Index* policy variable. This approach results in a significantly larger estimate for the impact of tax support, which rises to a gross RDIR estimate of nearly 1.6, implying net additionality. This estimate is rather imprecise, so it is still not possible to reject the hypothesis a neutral effect scenario (RDIR=1). The econometrics literature helps interpret this higher estimated effect as, the IV approach identifies the impact of a growth in tax expenditures among countries where this costs that respond effectively to the introduction of more generous subsidy rates. In other words, this effect may not be generalisable to all instances as in some cases, more generous provisions do not necessarily translate into higher, contemporary tax support being received by firms. This therefore calls for some caution.

Direct funding vs. R&D tax support

It is possible to compare the short term gross additionality of R&D support to business provided through tax incentives and direct funding by comparing the RDIR estimates in **Table 7**. These suggest that one unit of direct funding translates into 1.09 and 1.18 units of business total R&D investment in the short-run. This implies that one unit of direct funding yields an additional 0.09 and 0.18 units of business R&D investment, respectively. These amounts are however, not precisely estimated enough to reject the hypothesis that the net effect is null or that the RDIRs for the two instruments are different.[66]

Overall, direct government funding appears to entail a slightly higher degree of R&D input additionality than tax incentives, except for the specification where tax support is instrumented through the *B-Index*. It is not possible to carry out a similar IV estimation for direct support. When similar specifications are used, the estimates suggest that direct funding is at worst neutral while tax incentives tend to be associated with a variable degree of crowding out. Also when both policy variables are treated similarly (i.e. as exogenous variables), the effects of actual tax support tend to be slightly less variable than those for direct support, probably reflecting a much wider diversity of approaches to granting discretionary support.

It is plausible that direct support for R&D appears to have a small edge on average over R&D tax incentives in terms of additionality. Owing to the typically non-discretionary nature of the latter, whereby all qualifying firms stand to benefit from R&D tax support, it is not possible to incorporate assessment criteria based on counterfactuals in allocating tax support. In other words, R&D tax incentives, implemented as non-discretionary measures, are not suitable for expert judgement about whether a firm have invested in R&D had it not received support, and excluding firms from support on such basis. Assessments and approvals can at most limit themselves to setting out whether the firm has presented a project description (ex-ante) or carried out a project (ex post) that qualifies as eligible R&D activity and whether it meets the objective conditions to be subject to a certain, more or less favourable regime. Discretionary direct support schemes can to some extent introduce such checks and embedding them on the allocation of resources, although it is worth highlighting that the assessment of additionality by a third party can never be fully rendered objective. Discretionary funding allocation powers can also have both intended and unintended consequences, possibly allowing to better targeting of support towards firms, activities or projects that appear to yield higher additionality and/or larger spillovers, but may also be directed to better connected firms while implying significant bureaucratic costs for both government and firms.

5. Concluding Remarks

A new OECD data resource for R&D policy analysis

R&D tax incentives have become a key policy instrument for governments to incentivise business and economy wide R&D. Since 2007, OECD has been actively collecting data on the design and the cost of R&D tax incentives in close collaboration with the OECD-NESTI network of experts. The objective of this data collection is to improve the existing evidence on the use and impact of R&D tax incentives. This is done by allowing cross-country comparability of R&D provisions as well as with direct measures of government support.

The OECD R&D Tax Incentives database represents the output of this collaborative data collection effort. The database provides two novel indicators that facilitate a comprehensive comparison of governments' efforts to provide tax relief for R&D over two decades: (a) a consistent time series of implied tax subsidy rates (*B-Index)* for four major scenarios; and (b) for the first time, an internationally comparable time-series on the total cost of tax support (GTARD). The two series offer a complementary view into the use and cost of this policy instrument, firstly by modelling and comparing the design of R&D tax incentives across countries by means of a set of reference marginal "subsidy rates"; and secondly by comparing the actual total support received by firms across countries. The latter allows accounting for other factors that affect tax relief, e.g. firm (group or project) level restrictions to relief, exclusion restrictions with respect to alternative forms of support; and the demand for support, e.g. uptake and use of the R&D tax provision by firms.

These indicators facilitate the descriptive analysis of the trends in the generosity of R&D tax subsidy rates and their translation into tax relief amounts. The combination of both forms of support (direct and indirect) characterise key aspects of the policy-mix used by governments to support R&D and its changes over time. The database documents an increase over the past two decades in the availability of R&D tax incentives (**Section 3.1**), a rise in the generosity of implied subsidy rates (**Section 3.2.2**) and, with few exceptions, a generalised shift towards this type of support versus direct funding (**Section 3.3.1** and **3.3.2**), largely facilitated by the existence of international rules that make this type of support relatively easier to implement.

Demonstrating the use of the R&D tax incentives database

The release of this database for public use opens up a number of possible avenues for empirical research in this area. The empirical application in this paper demonstrates the use of both time series in investigating the impact of tax support on the R&D conducted by firms in OECD countries over a period spanning nearly two decades. In addition to replicating econometric studies on the effect of changes in the user cost of R&D (hitherto limited to a reduced set of OECD countries) which yield a short run price-elasticity of R&D of close to -0.12, this paper has provided for the first time in a cross-country setting, a series of estimates that specify the response (elasticity) of R&D to the actual amount of tax relief received by firms (GTARD). This analysis has yielded positive elasticities of R&D expenditure to GTARD in the short-run of 0.02 to 0.04. Of particular relevance is the ability to use the *B-Index* as an instrument to correct the endogeneity of GTARD. A series of robustness tests confirm these results.

Policy-makers interested in gauging the ability of R&D tax incentives to induce *additional* R&D in the market economy can find in this paper a demonstration on how to derive R&D incrementality ratios for R&D tax support and direct government funding of business R&D. The results indicate that, by and large, both types of support contribute at least to a gross increase in R&D performance in the business sector, although it is not possible to find strong evidence of net R&D additionality *over and above* the direct cost (to government) of the support measures. Estimated R&D incrementality ratios for tax incentives range from 0.18 when a traditional indirect approach method is used based on the notion of user cost of R&D to 0.88 when using actual data on the contemporary cost of tax support. This compares to 0.85 to 1.18 in the case of direct support, which is less precisely estimated probably due to the wider range of instruments and implementation practices when it comes to direct support for R&D. While direct support, as in many country-level studies, is considered an exogenous policy variable, tax support is recognised to be potentially endogenous. When the endogeneity of tax support is taken into account, the results suggest that R&D tax incentives may have a fiscally neutral or even net additional effect among countries where tax expenditures respond to policy design changes.

Policy and research implications of the analysis

Interpreting the additionality results

The additionality of direct support for R&D appears to be slightly but not statistically significantly higher than for R&D tax incentives when analysed in a comparable fashion. As discussed in the previous section, this can be considered as a necessary consequence of the predominantly non-discretionary nature of tax support. A likely trade off arises between the ability to select the projects with potentially highest additionality, and the ability to channel support to firms without directing the R&D activity while at the same time complying with international trade and competition rules. Direct measures of support can be better targeted towards activities, firms and areas where higher additionality and spillovers could be generated. However this comes at the expense of higher costs of administration and higher compliance costs for firms. Our study suggests that at the margin, many countries are substituting indirect tax support for direct government funding for R&D, i.e. engaging in a re-orientation of financial support to business R&D. An optimal policy mix will likely require a combination of both direct and indirect support instruments.

Policy makers may wonder whether R&D tax incentives are after all good value for money. This paper does not provide all the necessary tools for such assessment, which will often vary on a country-by-country basis. The finding of a partial crowding out effect does not necessarily mean that R&D tax relief measures are inefficient–their net benefit can still be positive if the combined private and social returns to R&D are sufficiently high. When no direct evidence can be gauged of such economic effects, policy makers can combine evidence on the additionality of support with evidence on the types of impacts associated with the type of R&D activities that appear to be stimulated by their policies.

It is also worth noting that the results presented in this paper are not evaluation results but inferences based on cross country variation over time in business R&D performance and funding, as well as new measures of public support for business R&D.

Implications for future work – integrating the micro perspective

Estimates of input additionality based on macro-level data have both advantages and disadvantages relative to those based on micro-level data (Hall and Van Reenen, 2000[33]). Cross-country analyses exploit the cross-country and temporal variation in the design and rate of tax support to assess the overall impact of R&D tax incentives on R&D expenditure within countries, including spillovers across firms in that country. However, macro-level estimates represent averages over the whole support of firms and may well differ from those estimated at the micro level. The degree of additionality or substitutability of tax support and other forms of government support is likely to differ by type of firm and may vary with the level of support (Appelt et al., 2016[34]). If tax relief has a relatively large impact on firms with low R&D levels but less so on those with high, estimates at the micro level may be significantly larger than estimates based on aggregate data. Firms' R&D efforts in response to policy changes may vary depending whether policy changes are perceived to be permanent or transitory. The magnitude of public support may thus vary over time and be also affected by firms' R&D investment behaviour and its persistency.

The additionality of R&D tax incentives may also vary with their design and with the use of direct funding or other forms of government support. This would be one avenue of research to further explore in the future, in particular through distributed microdata work where the variation in design features can be exploited at much lower levels of data aggregation. Similarly, in the case of direct support additionality is found to vary with the type of instrument used and its design (Czarnitzki and Lopes-Bento, 2014[35]; Huergo and Moreno, 2017[36]). All in all, these considerations highlight the importance of complementing cross-country and micro-level approaches in estimating the effectiveness of R&D tax support across and within OECD countries.

The indicators presented in this report provide a resource for further analysis of the impact of R&D tax support and a complement to distributed microdata work currently being carried at the OECD through the microBeRD project. Future work will delve into the heterogeneity of the responsiveness of business R&D to tax support across different dimensions, i.e. design of the incentives, firm characteristics, and industry structure. The impact on other innovation activities and outcomes is a natural target for follow-on work. As R&D tax incentives and, particularly their effectiveness, are complex objects of study, the combination of different methods of evaluation and their assessment from different perspectives is called for. This includes assessing the extent to which reporting of R&D statistics can be influenced by the provision of government support. The ultimate aim is for this new database to become a widely used resource and to continue update and enhance its relevance in collaboration with data providers and users from the policy and research community.

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Annex A. The *B-Index* calculation: Examples

This section presents three examples that illustrate the *B-Index* calculation for a fictitious country, Country A. The *B-Index* represents the tax component of the user cost of R&D and summarises both the general aspects of the tax system and the provisions that are specific to lowering the cost of performing R&D to the firm. The *B-Index* is computed as,

$$BIndex = \frac{ATC}{1-\tau} = \frac{1-\mathrm{A}}{1-\tau} \qquad \text{A.1.}$$

The numerator of the *B-Index*, ATC, specifies the after-tax cost of R&D to the firm, taking into account the net present value of baseline and enhanced tax deductions for R&D ($\mathrm{A} = \mathrm{A}_{basline} + A_{enhanced}$). Baseline tax deductions correspond to the standard tax treatment of current expenditure and capital assets that are non-specific to R&D. Enhanced tax allowances apply exclusively to qualifying R&D expenditures (current and/or capital). This enhanced tax deductions can take the form of R&D tax credits, allowances or exemptions and may reduce the CIT base or SSC/payroll taxes.

The after-tax cost of one additional unit of R&D investment can be written as:

$$ATC = 1 - \mathrm{A}_{baseline} + A_{enhanced} \qquad \text{A.2.}$$

Example 1:

Baseline tax deductions: In Country A, all current expenditures are fully deductible (expensing) and capital expenditure can be immediately write-off. The CIT rate is 30%.

Enhanced R&D tax deductions: Country A offers a **volume-based R&D tax credit of 10**%. Eligible R&D expenditures include current R&D expenditures, the purchase of machinery and equipment and the purchase of buildings and land.

Since the baseline treatment of current expenditure is expensing, the baseline deduction is simply equal to the CIT rate. In deriving the ATC and *B-Index* estimate, a common 60:30:5:5 percentage distribution of labour, other current, machinery and equipment, and building expenditures is applied based on average estimates for OECD countries (www.oecd.org/sti/rds). A weight of 0.9 (0.1) thus applies to current (capital) expenditure.

$$ATC = 1 - 0.9 * \left(\underbrace{1 * 0.3}_{A_{baseline}} + \underbrace{0.1}_{A_{enhanced}} \right) - 0.1 * \left(\underbrace{1 * 0.3}_{A_{baseline}} + \underbrace{0.1}_{A_{enhanced}} \right) \qquad \text{A.3}$$

$$BIndex = \frac{0.6}{1-0.3} = 0.67 \qquad \text{A.4}$$

The implied marginal R&D tax subsidy for one additional unit of R&D outlay is equal to:

$$1 - BIndex = 0.33 \qquad \text{A.5}$$

Example 2:

Baseline tax deductions: In Country A, all current expenditures are fully deductible (expensing) and capital expenditure can be immediately write-off. The CIT rate is 30%.

Enhanced R&D tax deductions: Country A offers a **volume-based R&D tax allowance of 10%**. Eligible R&D expenditures include current R&D expenditures, the purchase of machinery and equipment and the purchase of buildings and land.

$$ATC = 1 - 0.9 * \left(\underbrace{1 * 0.3}_{A_{baseline}} + \underbrace{0.1 * 0.3}_{A_{enhanced}} \right) - 0.1 * \left(\underbrace{1 * 0.3}_{A_{baseline}} + \underbrace{0.1 * 0.3}_{A_{enhanced}} \right) \quad \text{A.6}$$

$$B - Index = \frac{0.67}{1 - 0.3} = 0.95 \quad \text{A.7}$$

The implied marginal R&D tax subsidy for one additional unit of R&D outlay is equal to:

$$1 - BIndex = 0.05 \quad \text{A.8}$$

Example 2 considers an R&D tax allowance while Example 1 shows the case of an R&D tax credit. All features of the tax system are the same. The tax subsidy rate is lower in the case of an R&D tax allowance as R&D tax allowances are deductions on taxable income, while R&D tax credits reduce the tax liability of the firm.

Example 3:

Baseline tax deductions: In Country A, all current expenditures are fully deductible (expensing). Capital expenditures are depreciated at a rate of 5%, using the declining-balance method. The CIT rate is 30%. A nominal interest rate of 10% applies. The net present value of capital depreciation allowances amounts to:

$$Z^{ME,BL} = \frac{\varphi}{\varphi + i}(1 + i) = \frac{0.05}{0.05 + 0.1}(1 + 0.1) = 0.37 \quad \text{A.9}$$

Enhanced R&D tax deductions: Country A offers a **payroll withholding tax credit 18%**. Eligible R&D expenditures include labour R&D expenditures. Payroll and social security related incentives are effectively taxable, reducing the expense base and increasing the taxable income of firms. Labour expenditures account for two-thirds of current R&D expenditures based on the weights adopted.

$$ATC = 1 - 0.9 * \left(\underbrace{1 * 0.3}_{A_{baseline}} + \underbrace{\frac{2}{3} 0.18 * (1 - 0.3)}_{A_{enhanced}} \right) - 0.1 * \left(\underbrace{0.37 * 0.3}_{A_{baseline}} \right) \quad \text{A.10}$$

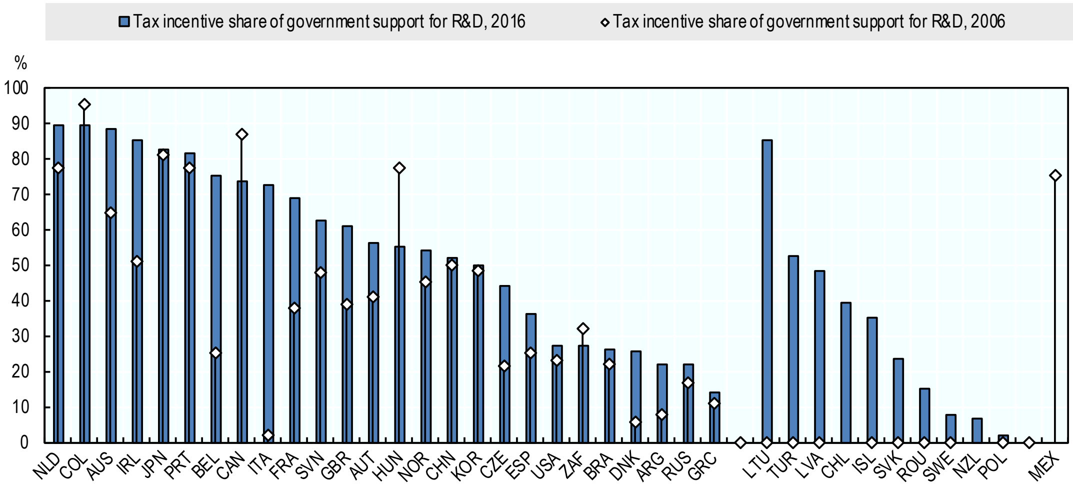
$$BIndex = \frac{0.62}{1 - 0.3} = 0.89 \quad \text{A.11}$$

The implied marginal R&D tax subsidy for one additional unit of R&D outlay is equal to:

$$1 - BIndex = 0.11 \quad \text{A.12}$$

Annex B. Additional figures

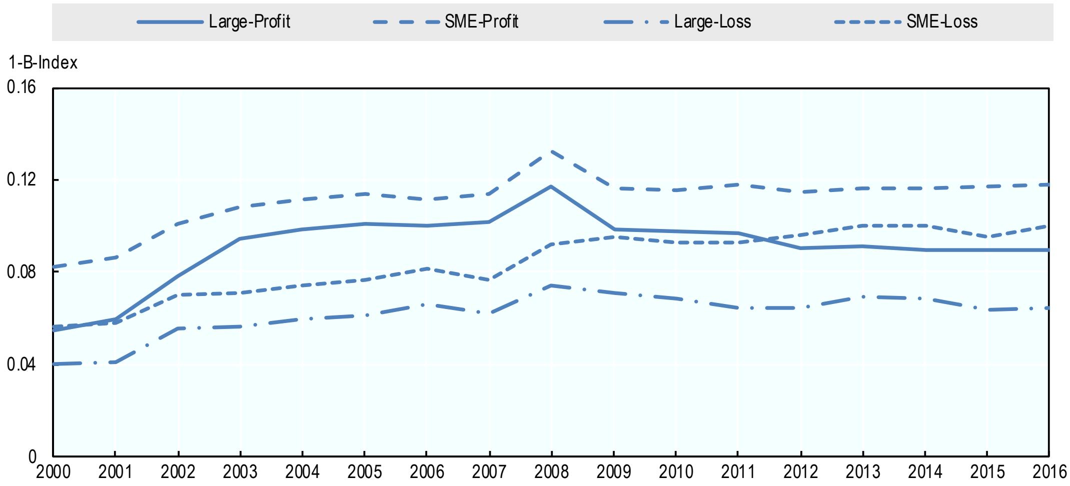
Figure B.1. Change in public support for BERD through direct funding and tax incentives, 2006-16



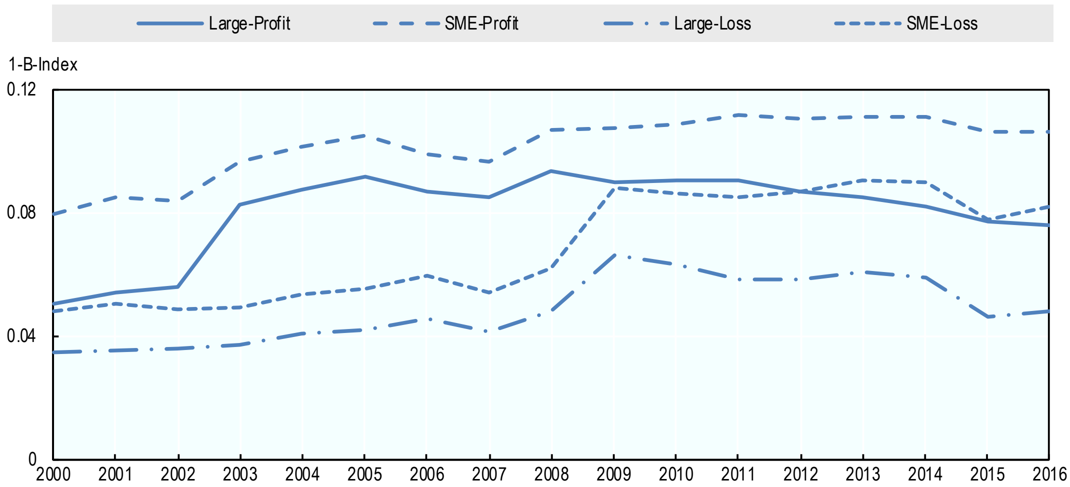
Note: Figures for Chile, Iceland, Lithuania, Latvia, Poland, New Zealand, Romania, the Slovak Republic, Sweden, and Turkey reflect the introduction of R&D tax incentives during the 2006-16 period, and those of Mexico the repeal of R&D tax incentives in 2009 (R&D tax incentives were reintroduced in Mexico in 2017).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Figure B.2. Implied R&D tax subsidy rates: aggregate trends, 2000-2018, OECD countries

Panel A: Implied R&D tax subsidy rates, weighted OECD average (weighted by GDP)



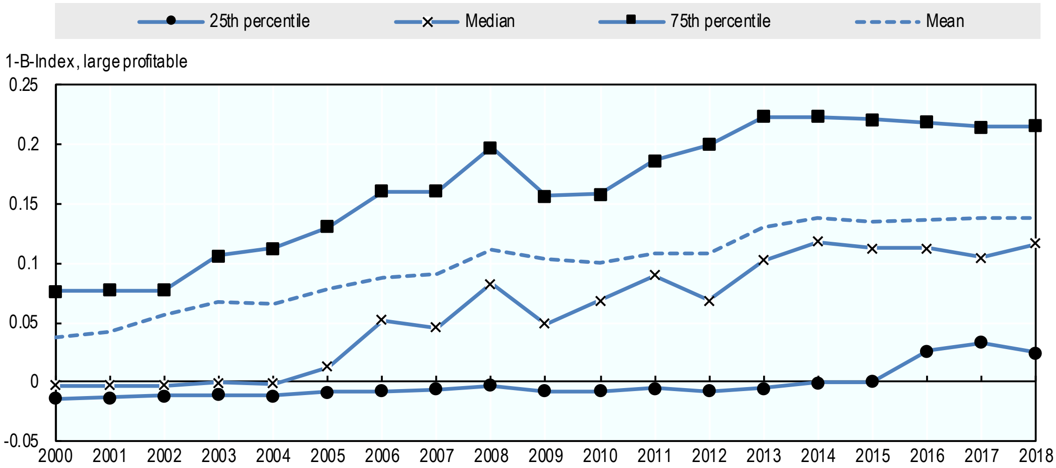
Panel B: Implied R&D tax subsidy rates, weighted OECD average (weighted by BERD)



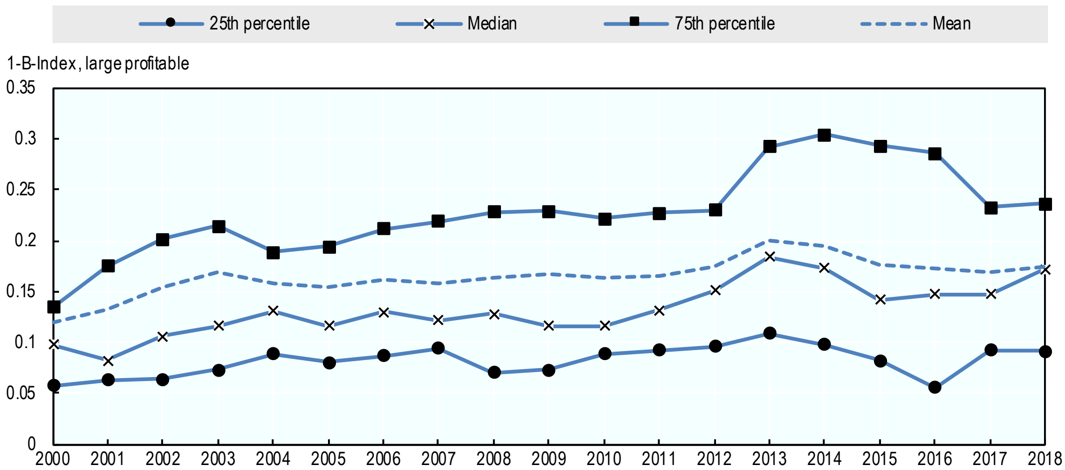
Note: Figures reflect the tax treatment of R&D expenditure for SMEs and large enterprises in OECD countries including those that do not offer tax incentive support for business R&D expenditure. Figures for Greece apply to the 2004-2017 period, and for Turkey, figures refer to 2008-2018. Figures do not reflect preferential provisions for start-ups, young firms or a specific subset of SMEs (e.g. innovative SMEs).
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Figure B.3. Implied subsidy rates for large profitable enterprises, OECD countries, 2000-18

Panel A: Countries with and without R&D tax incentives



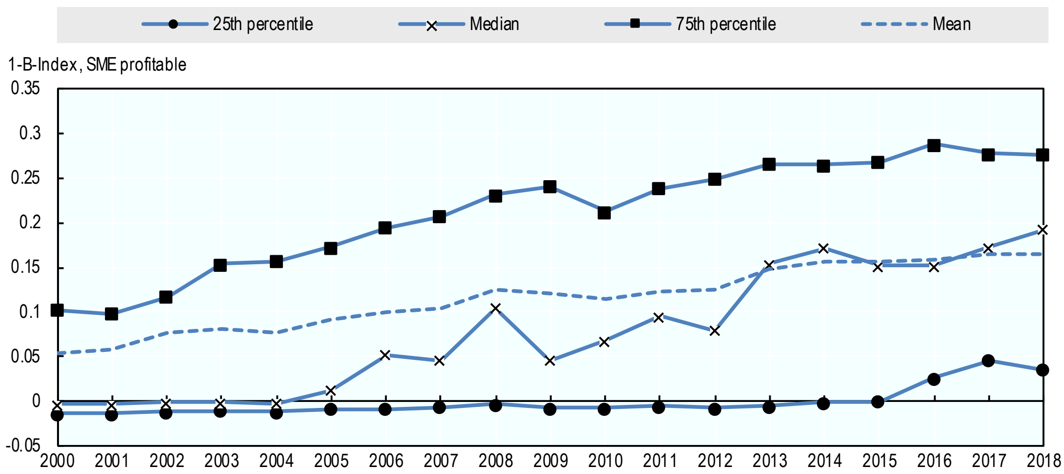
Panel B: Countries with R&D tax incentives



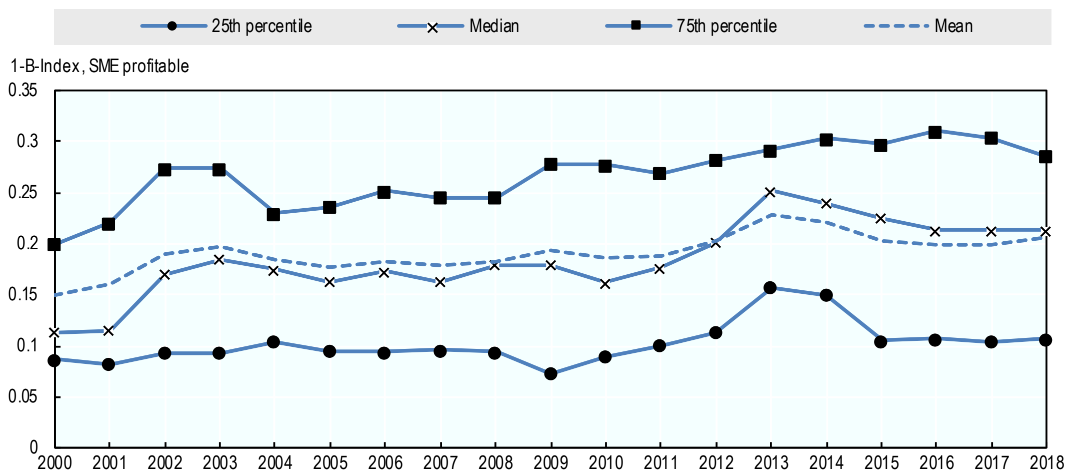
Note: Figures reflect the tax treatment of R&D expenditure for large profitable enterprises in OECD countries. Figures for Greece apply to the 2004-2017 period, and for Turkey, figures refer to 2008-2018.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Figure B.4. Implied subsidy rates for profitable SMEs, OECD countries, 2000-18

Panel A: Countries with and without R&D tax incentives



Panel B: Countries with R&D tax incentives



Note: Figures reflect the tax treatment of R&D expenditure for SME profitable enterprises in OECD countries. Figures for Greece apply to the 2004-2017 period, and for Turkey, figures refer to 2008-2018.

Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Annex C. Overview of findings in related literature

Table C.1. Estimation approaches and results of related macroeconomic studies

		Dependent variable	Main covariates	Method	Price elasticity Short-run	Elasticity to Direct Funding Short-run	AR(1)	Price elasticity long-run	Elasticity Direct Funding Long-run
Bloom et al. (2002)	9 OECD countries (1979-1997)	Manufacturing BUSBERD and BUSBERD/GDP (logs)	User cost (logs)	FE-IV, instruments the user cost with the tax component.	-0.144	n.a.	0.868	-0.813	n.a.
Guellec and Van Pottelsberghe De La Potterie (2003)	17 OECD countries 1983-1996	Business-funded BERD (logs)	*B-Index* Direct Funding (logs)	First-difference in logs; 3sls to instrument lag of the dependent	-0.283	0.072	0.083	-0.31	0.08
Falk (2006)	21 OECD countries (1975-2002)	BERD as % GDP (logs)	*B-Index*, Direct support (% GDP); (logs)	FD GMM and System GMM	-0.22	0.03[ns]	0.74	-0.84	
Montmartin (2013)	25 OECD countries (1990–2007)	Business-funded BERD (logs)	*B-Index*, Direct support (% GDP) (logs)	CLSDV	-0.11	-0.007[ns]	0.913	-1.31	
Montmartin and Herrera (2015)	25 OECD countries (1990-2009)	Business-funded R&D as % GDP (logs)	*B-Index*, Direct funding of BERD (% BERD) (logs)	GMM and CLSDV; First-difference logarithms	-0.198	-0.045	0.434	-0.35	-0.08
Thomson and Jensen (2013)	25 OECD countries (1983-2006)	Number of Employees (logs)	After-tax cost of labour and After-tax cost of capital	GMM	-0.181	0.0299	0.862	-1.31	0.22
Thomson (2017)	26 OECD countries; 29 industries (1987-2006)	Aggregate R&D investment of the industry (logs)	*B-Index*	GMM	-0.5	n.a.	0.876	-4.03	n.a.

Note: This summary is confined to selected empirical studies using aggregated country or industry-level data. A superscript 'ns' accompanies estimates that do not attain statistical significance at conventional levels; 'n.a' indicates the variable is not considered in the analysis. "Long run" elasticities correspond effectively to estimates of elasticity of the dependent variable over the long run relative to a permanent change in the independent variable. These estimates coincide with a measure of the cumulative change over time, without applying any form of discounting, driven by a one-off change in the independent variable. On a number of occasions, authors are not explicit about which of the two concepts they refer to when alluding to long run impacts.
Source: OECD analysis based on a review of the literature.

Annex D. Supplementary tables

Table D.1. Business-funded R&D intensity and the cost of performing R&D, 2000-16

Estimation as % of GDP

Country-set	Same countries as in Bloom et al. (2002)			Extended group of OECD countries					
				with R&D tax incentives			with and without R&D tax incentives		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Method	FE	FE	FE-IV	FE	FE	FE-IV	FE	FE	FE-IV
	Static	Dynamic	IV	Static	Dynamic	IV	Static	Dynamic	IV
Dependent variable	log BUSBERD_GDP t			log BUSBERD_GDP t			log BUSBERD_GDP t		
log BUSBERD_GDP t-1		0.941***	0.921***		0.891***	0.854***		0.777***	0.828***
		(0.0444)	(0.0453)		(0.0338)	(0.0418)		(0.0753)	(0.0430)
log *B-Index* t	-0.131*	-0.117***	-0.117***	-0.489***	-0.0953	-0.111	-0.490***	-0.144**	-0.122*
	(0.0795)	(0.0338)	(0.0337)	(0.125)	(0.0653)	(0.0679)	(0.125)	(0.0718)	(0.0674)
Observations	120	120	120	228	228	228	244	244	244
Countries	9	9	9	19	19	19	21	21	21
Kleibergen-Paap Wald F			168.77			203.48			191.25
Anderson Rubin Chi			148.88			202.10			202.77
(p-value)			(0.00)			(0.00)			(0.00)
Underidentification			24.96			62.60			64.02
(p-value)			(0.00)			(0.00)			(0.00)
Hansen J			2.37			0.47			2.49
(p-value)			(0.12)			(0.49)			(0.11)

Note: All regressions contain country and year fixed effects and control for structural breaks in Portugal (2008). Missing values are not imputed. Estimation (1)-(3) include the same set of countries as Bloom et al. (2002): Australia, Canada, Germany, Spain, France, United Kingdom, Italy, Japan and USA. OECD in (4)-(6) include those that have R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. Estimations (7)-(9) include the former and Germany and Luxembourg. In (3), (6) and (9) the lag of the business-funded R&D intensity is treated as endogenous and instrumented with its second and third lag. Standard errors in parenthesis are robust to heteroskedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Table D.2. BERD impact of government support for R&D: Alternative sample

Countries with continuous provision of R&D tax support throughout the 2000-16 period

Country-set	**OECD countries with R&D tax incentives during the period 2000-16**					
	(1)	(2)	(3)	(4)	(5)	(6)
Method	FE	FE	FE-IV	FE	FE-IV	FE-IV
	Static	Dynamic	IV	Static	IV1	IV2
Dependent variable	log BUSBERD t					
log BUSBERD t-1		0.899***	0.883***		0.859***	0.858***
		(0.0302)	(0.0300)		(0.0288)	(0.0286)
log *B-Index* t	-0.376**	-0.129***	-0.133***			
	(0.168)	(0.0324)	(0.0350)			
Log GTARD t				0.0750***	0.0381***	0.0534***
				(0.0289)	(0.00863)	(0.0129)
Log Direct Funding t				0.182***	0.0243**	0.0299**
				(0.0370)	(0.0114)	(0.0128)
Log GDP t	1.684***	0.194**	0.220**	0.944***	0.0752	0.0534
	(0.222)	(0.0922)	(0.0955)	(0.359)	(0.103)	(0.103)
Observations	124	124	124	115	115	115
Countries	10	10	10	10	10	10
Kleibergen-Paap Wald F			326.79		344.31	24.15
Anderson Rubin Chi			301.08		321.08	384.88
(p-value)			(0.00)		(0.00)	(0.00)
Underidentification			30.70		26.64	11.76
(p-value)			(0.00)		(0.00)	(0.00)
Hansen J			0.51		0.004	0.05
(p-value)			(0.48)		(0.95)	(0.83)

Note: All regressions contain country and year fixed effects. Estimation (1)-(6) include OECD countries that have R&D tax incentives in place throughout the period 2000-16: Australia, Canada, Denmark, France, Hungary, Japan, Korea, Spain, United Kingdom and the United States. Missing values are not imputed. Estimations (1)-(3) consider the *B-Index* as the policy variable of interest; and (4)-(6) consider government support for business R&D through direct funding and tax support. Estimations (2) and (5) treat business-funded BERD as endogenous and is instrumented using the second and third lag of business-funded BERD. Estimation (6) also controls for the endogeneity of GTARD using the *B-Index* as an instrument. Standard errors in parenthesis are robust to heteroskedasticity. Stars indicate significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Table D.3. Business-funded BERD impact of public support for R&D: Weighted regressions

Observations weighted by GDP

Country-set	Same countries as in Bloom et al. (2002)			Extended group of OECD countries: with R&D tax incentives			Extended group of OECD countries: with and without R&D tax incentives		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Method	FE	FE	FE-IV	FE	FE	FE-IV	FE	FE	FE-IV
	Static	Dynamic	IV	Static	Dynamic	IV	Static	Dynamic	IV
Dependent variable:		log BUSBERD t			log BUSBERD t			log BUSBERD t	
log BUSBERD t-1		0.897***	0.854***		0.893***	0.841***		0.882***	0.835***
		(0.0586)	(0.0607)		(0.0376)	(0.0472)		(0.0376)	(0.0454)
log *B-Index* t	-0.184***	-0.129***	-0.132***	-0.357***	-0.128*	-0.141**	-0.361***	-0.131**	-0.144**
	(0.0703)	(0.0426)	(0.0453)	(0.109)	(0.0663)	(0.0684)	(0.110)	(0.0665)	(0.0661)
log GDP t	-0.0839	0.115	0.105	0.992***	0.0697	0.124	0.999***	0.0923	0.140
	(0.234)	(0.110)	(0.123)	(0.258)	(0.0895)	(0.101)	(0.256)	(0.0901)	(0.0970)
Observations	120	120	120	228	228	228	244	244	244
Countries	9	9	9	19	19	19	21	21	21
Kleibergen-Paap Wald F			85.18			181.56			182.88
Anderson Rubin Chi			83.11			169.30			168.06
(p-value)			(0.00)			(0.00)			(0.00)
Underidentification			33.25			50.82			51.71
(p-value)			(0.00)			(0.00)			(0.00)
Hansen J			4.12			0.00			0.01
(p-value)			(0.04)			(0.998)			(0.9)

Note: All regressions contain country and year fixed effects. Missing values are not imputed. The regressions in this table are weighted by GDP to capture the differential impact of tax policy in economies of different scale. This table is the weighted version of Table 3. Estimation (1)-(3) include the same set of countries as Bloom et al. (2002): Australia, Canada, Germany, Spain, France, United Kingdom, Italy, Japan and USA. OECD in (4)-(6) include those that have R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. Estimations (7)-(9) include the former and Germany and Luxembourg. In (3), (6) and (9) the lag of business-funded BERD is treated as endogenous and instrumented using the second and third lag of business-funded BERD. Standard errors in parenthesis are robust to heteroskedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.

Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019

Table D.4. BERD impact of government support for R&D: Alternative specifications

Robustness to the inclusion of the corporate income tax rate (CIT) and long-term interest rate

Country-set	OECD (with R&D tax incentives)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Method	FE	FE	FE-IV	FE	FE	FE-IV	
	Static	Dynamic	IV	Static	Dynamic	IV1	IV2
Dependent		log BUSBERDt			log BUSBERDt		
log BUSBERD t-1		0.856***	0.837***		0.798***	0.775***	0.770***
		(0.0342)	(0.0379)		(0.0350)	(0.0433)	(0.0447)
log *B-Index* t	-0.418***	-0.102*	-0.109*				
	(0.116)	(0.0589)	(0.0594)				
log GTARD t				0.0391***	0.0222***	0.0224***	0.0453***
				(0.0136)	(0.00456)	(0.00480)	(0.0152)
log Direct Funding t				0.115***	0.00548	0.00720	0.0128
				(0.0269)	(0.0135)	(0.0138)	(0.0142)
CIT t	-0.112	-0.152	-0.151	1.119***	0.147	0.154	0.110
	(0.545)	(0.193)	(0.194)	(0.434)	(0.184)	(0.187)	(0.201)
Real LIR t	0.0276***	0.00705	0.00752	0.0188***	0.00573	0.00614	0.00516
	(0.00779)	(0.00528)	(0.00524)	(0.00492)	(0.00487)	(0.00484)	(0.00490)
log GDPt	0.386	-0.0232	-0.0139	-0.0597	-0.0766	-0.0617	-0.0852
	(0.251)	(0.0924)	(0.0932)	(0.226)	(0.0927)	(0.0973)	(0.105)
Observations	219	219	219	193	193	193	193
Countries	18	18	18	18	18	18	18
Kleibergen-Paap Wald F			266.03			232.98	17.37
Anderson Rubin Chi			262.42			173.41	180.89
(p-value)			(0.00)			(0.00)	(0.00)
Underidentification			58.24			47.99	25.75
(p-value)			(0.00)			(0.00)	(0.00)
Hansen J			0.25			1.19	0.6
(p-value)			(0.62)			(0.28)	(0.44)

Note: All regressions contain country and year fixed effects. Missing values are not imputed. Real long-term interest rates are calculated as difference between nominal 10-year benchmark government bond yields (OECD, 2019[25]) and contemporary year-on year core inflation rates. Core inflation excludes prices of food and energy. Estimation (1)-(7) include OECD countries with R&D tax incentives in place for at least 5 years: Australia, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Norway, Portugal, Slovenia, Spain, the United Kingdom and the United States. Information on long-term interest rates is not available for Turkey. The policy variable in estimations (1)-(3) is the *B-Index*; and GTARD for estimations (4)-(7). Estimations (1)-(3) are comparable to columns (4)-(6) in **Table 3**. Estimations (4)-(6) treat GTARD as exogenous. Estimation (7) is comparable to column (2) in **Table 5** and treat GTARD as endogenous using the *B-Index* as an instrument. In (3), (6) and (7) the lag of business-funded BERD is treated as endogenous and instrumented using the second and third lag of business-funded BERD. Standard errors in parenthesis are robust to heteroskedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Table D.5. Public support for R&D and R&D investment, 2000-16: Sample with imputations

Country-set	Extended group of OECD countries with R&D tax incentives					
	(1)	(2)	(3)	(3a)	(3b)	(3c)
Method	FE	FE-IV		FE-IV		
	Static	IV1	IV2	First	First	Reduced-form
Dependent variable:	logBUSBERD t	logBUSBERD t	logBUSBERD t	logBUSBERD t-1	logGTARD t	logBUSBERD t
logBUSBERD t-1		0.807***	0.793***			
		(0.0353)	(0.0366)			
logGTARD t	0.0406***	0.0205***	0.0474***			
	(0.0132)	(0.00452)	(0.0156)			
logDirect Funding t	0.134***	0.0167	0.0226*	0.0201	-0.233*	0.0272
	(0.0293)	(0.0127)	(0.0131)	(0.0158)	(0.132)	(0.0198)
logGDPt	0.239	0.0135	0.0125	-0.0705	0.423	-0.0199
	(0.218)	(0.0969)	(0.102)	(0.101)	(0.791)	(0.139)
log*B-Index* t				-0.177***	-3.001***	-0.269***
				(0.0503)	(0.490)	(0.0589)
logBUSBERD t-2				0.778***	0.962	0.701***
				(0.0861)	(0.592)	(0.111)
logBUSBERD t-3				0.0355	-0.779	-0.0488
				(0.0814)	(0.559)	(0.116)
Observations	240	240	240	240	240	240
Countries	21	21	21	21	21	21
Kleibergen-Paap Wald F		306.3	12.96			
Anderson Rubin Chi		291.99	317.2			
(p-value)		(0.00)	(0.00)			
Underidentification		54.37	18.96			
(p-value)		(0.00)	(0.00)			
Hansen J		0.61	0.21			
(p-value)		(0.43)	(0.64)			

Note: All regressions contain country and year fixed effects. Estimation (1)-(4) include OECD countries with R&D tax incentives in place for at least 5 years between the period 2000-16: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Slovenia, Spain, Turkey, United Kingdom and the United States. Missing values are imputed using averages and thus Austria and the Netherlands (on the previous before its structural break) enter the analysis. Estimation (3) treats business-funded BERD as endogenous and is instrumented using the second and third lag of business-funded BERD. Estimation (4) also controls for the endogeneity of GTARD using the *B-Index* as an instrument. Standard errors in parenthesis are robust to heteroskedasticity. Stars indicate statistical significance at the 1% (***), 5% (**), 10% (*) level.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Table D.6. Robustness of estimated R&D incrementality ratios (RDIRs) for tax and direct support, calibrated at different mean values

Calculation of RDIR:	**Method 1**	**Method 2**				
	(1)	(2)	(3)	(4)	(5)	(6)
Specification	**Table 3** Column (6)	**Table 4** Column (4)	**Table 5** Column (2)	**Table 5** Column (3)	**Table D.5** Column (2)	**Table D.5** Column (3)
Panel A: Gross incrementality ratio for R&D tax support (Additionality benchmark=1)						
Tax support variable	*B-Index*	*B-Index*	GTARD	GTARD	GTARD	GTARD
A.1.: Calibration at the unweighted mean						
RDIR	0.177	0.165	0.873	1.572	0.763	1.761
Standard error	0.1	0.101	0.176	0.592	0.168	0.581
A.2.: Calibration at the weighted mean						
RDIR	0.177	0.165	0.415	0.748	0.363	0.838
Standard error	0.1	0.101	0.084	0.282	0.08	0.276
Panel B: Gross incrementality ratio for government direct funding (Additionality benchmark=1)						
Direct Support variable	-	Direct Funding	Direct Funding	Direct Funding	Direct Funding	Direct Funding
B.1.: Calibration at the unweighted mean						
RDIR		0.847	1.094	1.175	1.314	1.425
Standard error		0.279	0.269	0.273	0.239	0.246
B.2.: Calibration at the weighted mean						
RDIR		0.891	1.066	1.124	1.223	1.301
Standard error		0.198	0.191	0.194	0.17	0.175
Panel C: Parameters feeding into the calculation of IR						
C.1. Estimated R&D tax support (gross) and direct funding (net) coefficients						
AR(1)	0.87	0.876	0.829	0.822	0.807	0.793
Standard error	0.038	0.0398	0.038	0.039	0.0353	0.0366
Tax support variable	*B-Index*	*B-Index*	GTARD	GTARD	GTARD	GTARD
RDIR	-0.11	-0.102	0.0235	0.0423	0.0205	0.0474
Standard error	0.0636	0.064	0.005	0.016	0.0045	0.0156
Direct support	-	Direct Funding	Direct Funding	Direct Funding	Direct Funding	Direct Funding
RDIR	-	-0.008	0.0049	0.0093	0.0167	0.0226
Standard error		0.015	0.0143	0.0145	0.0127	0.0131
C.2.: Other parameters						
Unweighted mean	*B-Index*=0.84; CIT=0.27	BUSBERD_GTARD=37.19; BUSBERD_DF=18				
Weighted mean	*B-Index*=0.84; CIT=0.27	BUSBERD_GTARD=17.70; BUSBERD_DF=13.34				

Note: Panel C includes all relevant estimates and calibration parameters that enter the calculation of incrementality ratios reported in **Table 7** following Methods 1-3 described in **Section 4.2**. Specifications cited in each column refer to the tables in Section 4.2 and **Annex D**. Different calibration parameters are considered in Panel A and B using different moments of the distributions of the corresponding variables of interest. Standard errors for the incrementality ratios are computed using the delta-method.
Source: OECD analysis based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, March 2019.

Endnotes

[1] The full OECD R&D Tax Incentives Database, including metadata and methodological notes, can be downloaded from: https://oe.cd/ds/rdtax

[2] Since 2016, as part of the ongoing collaboration with the EU in this area, the OECD data collection includes all member states of the European Union, including those that are not OECD member countries, namely Bulgaria, Cyprus, Croatia, Malta and Romania.

[3] This includes Argentina, Brazil, Bulgaria, China, Colombia, Cyprus, Romania, the Russian Federation, and South Africa. Data for Croatia and Malta are pending validation.

[4] This includes Brazil, Bulgaria, China, Colombia, Cyprus, Romania, the Russian Federation and South Africa. Data for Argentina, Croatia and Malta are not available due to incomplete historic information on the design of R&D tax incentives over the 2000-18 period.

[5] For more details on this project, please visit http://oe.cd/microberd.

[6] Work is ongoing to secure differentiated reporting of grants from procurement within direct funding by countries to the OECD. Other forms of indirect support are currently not separately collected, such as repayable loans, which according to OECD *Frascati Manual* guidance are treated as business own funding. This might be the subject of future OECD R&D measurement work.

[7] In line with the OECD Frascati Manual (OECD, 2015[2]), R&D tax benefits are generally excluded from official figures of direct funding of BERD to ensure international comparability and avoid double-counting. Direct funding of BERD is in principle included in the taxable income of firms based on which tax benefits are computed. Depending on the treatment of grant-funded R&D projects (OECD, 2018[7]), firms may be able to combine direct and indirect sources of funding under the same R&D project. In several instances, R&D grants and other direct subsidies reduce the expense base for calculating R&D tax relief by an amount equivalent to the subsidy received.

[8] Accounting rules significantly restrict the instances in which R&D expenditures can be capitalised (IAS38) and implicitly confer significant discretion to firms as to whether to capitalise. To a first order of approximation and pending future analysis, this effect is considered to have a negligible impact on the relevant baseline.

[9] According to the 2015 OECD *Frascati Manual* (OECD, 2015[2]), Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge. For an activity to be considered as an R&D activity, it must satisfy five core criteria. The activity must be: novel, creative, uncertain, systematic, transferable and/or reproducible. R&D covers three types of activity: basic research, applied research and experimental development.

[10] Definitions of R&D for tax purposes are under continuous evolution and reinterpretation by national tax authorities, a feature that may also have an impact on the records kept by R&D performers. According to the 2015 OECD Frascati Manual (OECD, 2015[2]), particular care should be taken to check the actual R&D content of the tax relief provided by governments for innovation-related areas, particularly those relating to other innovation expenditures and expenditures on intellectual property rights or their commercialisation, which may not be an integral part of R&D

projects. One of the key features of R&D as defined by the OECD is that different activities which in some contexts would not be characterised as R&D, might be described and quantified as R&D if they are conducted as part of a project that fulfils the criteria for R&D (OECD, 2018[7]).

11 Known instances where tax incentives are provided at subnational level are Canada's provinces and states within the United States. For Canada, it is estimated that, on average, provincial R&D tax credits would raise tax support for R&D undertaken by CCPCs from 35% of eligible expenditures to nearly 45%, and would raise support for larger firms from 15% to approximately 22%.

12 For additional information on the type of GTARD estimates reported by countries, see http://www.oecd.org/sti/rd-tax-stats-gtard-notes.pdf.

13 Unfortunately, it is not common practice across all countries to back-cast data series for a long period of time after introducing methodological breaks, for example those aimed at capturing microenterprises. BERD data revisions are sometimes due to heightened awareness among statistical offices of hitherto unknown R&D performing firms following the introduction of support schemes such as R&D tax incentives.

14 In the modelling, the net present value of a volume-based R&D tax allowance equals $A\tau Z + \tau\theta Z$, where Z is the net present value of depreciation allowances. The method of depreciation is generally straight-line or declining-balance methods. Accelerated depreciation provisions are also in place in some countries (e.g. Austria, Israel, Estonia). Let i be the nominal interest rate, φ the capital allowance rate and τ the CIT rate, the net present value of depreciation allowances, Z, can be calculated in the case of the declining balance method as: $Z^{DB} = \frac{\tau\varphi}{\varphi+i}(1+i)$ and for the straight-line method as $Z^{SL} = \frac{\tau\varphi}{i}(1+i)\left(1-(1+i)^{-\frac{1}{\varphi}}\right)$ The nominal interest rate is assumed to be 10% and the inflation rate is set to 0.

15 A common 60:30:5:5 percentage distribution of labour, other current, machinery and equipment, and building expenditures is applied based on approximate average estimates for OECD countries (http://oe.cd/rds).

16 Tax credits represent taxable income in Canada and the United Kingdom (R&D tax credit for large companies) or are effectively taxable (Australia, Chile and the United States) because in order to claim the headline credit rates the taxpayer has to renounce to the deductibility of the R&D expenses that are claimed. In this case, the effective tax credit rate (net of tax) is: $c^{net}=c(1-\tau)$.

17 The treatment of grants can vary depending on the source of funds and by type of tax incentive scheme (OECD, 2018[7]).

18 Due to limited historical data on the distribution of eligible R&D spending with respect to ceilings and thresholds, the estimates are not adjusted for such provisions,

19 Governments can provide support to business R&D also through fundamental science and ideas originating from or developed within the government sector itself or publicly-funded institutions.

20 Following the rise of R&D tax incentives and market-based instruments more generally over the last decade, there is a recurring debate about the directionality of public support and capacity of different policy instruments to promote the achievement of Sustainable Development Goals (SDG) (Schot and Steinmueller, 2018[44]).

21 Since July 2013, New Zealand has operated a direct grant support scheme (R&D Growth Grants) with significant non-discretionary features. A reform of support was ongoing while preparing this report that is expected to lead to the abolition of this grant scheme and the reintroduction of tax-based relief for R&D.

22 In the loss-making scenario, marginal tax subsidies are typically lower unless refund provisions are in place, capturing firms' inability to fully use tax benefits in the current year. A more granular disaggregation of GTARD and BERD by firm size and profitability would be necessary to enhance the comparability between the two subsidy measures.

23 In this case, the weighted average implied tax subsidy rate would lie somewhere in between. The values reported for SMEs and large firms.

24 To review countries the eligibility of extramural expenditure by country refer to OECD (2018[4]).

25 Note that this graph assesses changes in the share of tax relief in the policy mix and implied tax subsidy rates comparing two reference points in time, 2006 and 2016. This provides an easy way of displaying cross-country time trends. However, the *OECD R&D tax incentives* database also allows country-specific trend analysis of both implied subsidy rates and the cost of tax relief. This type of analysis features in the country profiles produced by OECD and accessible at https://oe.cd/rdtax.

26 Similar although less pronounced upward trends although are visible when weighting the values for different countries into an OECD representative indicator. Weighted average tax subsidy rates account for the size of countries in terms of GDP or BERD. Each weighting can be suitable and informative depending on the policy question at hand. the OECD average by GDP (**Figure B.2**, Panel A) or BERD (**Figure B.2**, Panel B). **Figure B.3** illustrates the dispersion of R&D tax subsidy rates in OECD countries from 2000 from 2018, displaying the marginal rates of R&D tax subsidy for large firms and SMEs. **Figure B.4** does so in the profit scenario at different percentiles of the distribution. This facilitates a more nuanced analysis of aggregated (average) trends in marginal R&D tax subsidy rates in the OECD area and how these are linked to changes in the uptake vis-à-vis generosity of existing R&D tax incentives.

27 It is important to specify that as commonly estimated, “bang for the buck” refers to R&D impacts but not necessarily about value for money, a more general construct that also depends on the social value of the additional R&D induced by government support. For this reason we refer to R&D BFTB when using this term.

28 Estonia does not offer R&D tax incentives during 2000-16. However, the expensing provision for current and capital expenditures in Estonia imply that its *B-Index* equals one throughout time. Due to this lack of within-country temporal variation, Estonia is not included in the estimation.

29 The results are robust to different composition of the sample and different sample restrictions.

30 Estimates of direct funding of BERD reported for Austria in the *OECD R&D Tax Incentives* database differ from those reported in the OECD MSTI database. In Austria, R&D tax support is included in official estimates of direct government funding of business R&D. To avoid double counting, R&D tax support is removed from the direct funding estimates.

31 Two breaks in series (2009, 2013) are identified in the case of Chile. Due to insufficient number of observations when the controls for before and after breaks are specified, Chile cannot be included in the analysis.

32 The Netherlands feature exclusively in the analysis based on imputed data (BERD and direct funding of BERD are imputed where missing) due to infrequent reporting from 2000 to 2011.

33 Statistics refer to the non-imputed sample unless specifically stated.

34 Hall and Jorgenson (1969[9]) propose a framework to study the impact of tax policy in incentivising investment expenditure. They construct a measure of the user cost of capital (implicit rental value of capital) introducing the effect of investment tax credits. This framework has been extended in subsequent work to the context of R&D, e.g. Bloom et al. (2002[10]), Warda (2001[5]), OECD (2013[6]; 2018[7]), Pfeiffer and Spengel (2017[39]).

35 Thomson (2017[12]) adopts this approach with an industry-level specification.

36 Bloom et al. (2002[10]) use the tax component of the user cost to instrument the user cost (economic and tax component). The reduced-form equation used in this approach corresponds to the alternative approach of using the tax component directly, i.e. the *B-Index*, as the variable to capture the cost of performing R&D.

37 This exogeneity assumption may be challenged if governments use R&D tax incentives strategically (e.g. as a counterfeit measure in years of economic crisis), rendering the user cost of R&D (*B-Index*) a function of current R&D investment levels. This simultaneity is generally seen a pertinent issue in firm-level studies but less so in macroeconomic studies.

38 Other studies include R&D investment by entities in other institutional sectors (e.g. government R&D, R&D performed by higher education institutions), see (Guellec and Van Pottelsberghe De La Potterie, 2003[11]; Falk, 2006[13]). Note also that equation (2) can likewise be extended to incorporate the impact of these covariates on business R&D.

39 The amount of direct support from the government to business-performed R&D is part of BERD. Using BERD as the dependent variable would create automatic correlation between the dependent and direct funding.

40 The inclusion of the lagged dependent variable, the AR(1) coefficient, implies that estimated short- and long-run elasticities for the variables of interest may differ.

41 Errors may be clustered to correct for arbitrary heteroscedasticity and arbitrary within country correlation. The cluster-robust standard error estimator converges to the true standard error as the number of panels approaches infinity (Nichols and Schaffer, 2007[41]). Kézdi (2004[42]) show that 50 equally-sized clusters are a suitable number to ensure convergence. With a small number of clusters around 20 for this study and an unbalanced cluster size, this approach is not suitable.

42 The finite sample properties of the estimator are dependent on the power of the instruments, being instrument proliferation a common concern that may lead to a potential overfitting of the endogenous variable (Roodman, 2009[37]; 2009[38]). In system GMM, additional initial conditions apply. In practice, GMM specifications should be subject to a high degree of scrutiny in the impact of the instrument set used with respect to the validity of instruments and robustness of results.

43 Estimations in first-difference have the advantage of rendering I(1) variables stationary. This estimation strategy comes at the cost of missing observations, especially on a panel with gaps. A lower sample may reduce the power of the estimation. First difference estimation including a lagged dependent term is likewise affected by Nickell bias and endogeneity needs to be addressed. Lagged differences are poor instrumental variables with persistent variables such as business R&D. System GMM methods are adequate method to account for both the endogeneity caused by the lagged dependent in the presence of persistency in a short-panel. However, as discussed above, no instruments were found that would have passed the instrument validity tests and that were robust to different specifications. Due to the inability to satisfactorily address the endogeneity of the lagged dependent variable in the first-difference specification, a fixed-effects panel estimation is pursued.

44 Dumont (2017[19]) using firm-level data, instruments the regional subsidy by the average subsidisation rate aggregated to the 3-digit industry code and alternatively the total amount of support (net of support the support to the firm in question) aggregated to the 3-digit industry code level. In the case of microdata, variables aggregated at the industry/economy level are often potential instruments. In this study, based on country-level data, these solutions cannot be pursued. Wolff and Reinthaler (2008[28]) use as an instrument the share of public to private sector R&D investment but this would be endogenous in our cross-country specification.

45 In addition, year fixed effects are included in (2) and (3) to control for common aggregate shocks as well as technology shocks and the country fixed-effects for unobserved time-invariant characteristics of the countries. The effect of factors that might affect R&D, i.e. culture, but that are generally invariant over time would be captured within the fixed effects.

46 In some countries accrual-based estimates are not readily available and cash-based estimates are reported (**Section 2.1**). Under the cash-based approach, the cost of tax support is recorded the year it is paid out. It is however still reasonable to assume that the highest proportion of the cost of tax support in a given year corresponds to R&D conducted in the same year, and not that of the support earned in previous periods and paid out that year as a result of carry-overs. An estimation strategy using instrumental variables is proposed to address the measurement error in GTARD.

47 The logarithm specification considered in this study, i.e. equation (4) means that for countries and years in which tax support is zero, the logarithm is not defined. Adding a small constant so that the logarithm is defined is not an advisable strategy, as it affects statistical inference (Ekwaru and Veugelers, 2018[43]). Future work could consider specifications of this model that allow to capture countries with no R&D tax support. This includes the estimation of two-stage models, where the first equation establishes the probability of offering or not tax support; and the second equation establishes the amount of support offered. These models however face the difficulty of well-identifying the first-stage (selection) equation.

48 GTARD is broader than BERD whenever extramural (subcontracted) R&D expenditure qualify for tax support. Refer to **Section 2.1** for a broader discussion on this issue.

49 The *B-Index* is chosen as proxy for the user cost of R&D, $\rho_{it} \sim \mathrm{B} - \mathrm{Index}$. Using the tax component of the user cost of R&D avoids endogeneity issues arising from its economic component.

50 Note that equation (6) has the same form as equation (2) and (3) when the cost of performing R&D is proxied by the *B-Index*, $\rho_{it} \sim B - index$.

51 Studies that use BERD instead of BUSBERD as the dependent variable estimate a gross elasticity for direct support, as direct funding is one component of BERD.

52 Van Pottelsberghe De La Potterie (2003[11]) apply a similar approach and report net and gross effects.

53 In fact, the cost of tax support is defined as the cost of enhanced tax relief provisions over baseline tax deductions (expensing), where$\widehat{GTARD} = (\tau A - \tau) * BUSBERD$; where τA represents the value of baseline and enhanced deductions, and τ reflects the corporate income tax rate and value of baseline deduction. $\widehat{GTARD}$ therefore captures only the enhanced deductions for R&D expenditure.

54 Thomson (2017[12]) computes a similar derivation of the same formula but as a function of the after-tax cost (the numerator of the *B-Index*). The formula in Thomson (2017[12]) can be derived for a change in GTARD defining $RDTAXEXP = (1 - B) * BUSBERD$. Since in the derivation changes in the tax rate are assumed to be 0, changes to the *B-Index* are assumed to be only changes to the after-tax cost (numerator). The ATC is however also a function of the CIT rate, e.g. case of R&D tax allowances. The estimates of additionality in Thomson's paper can be seemingly obtained by using a flag value for the CIT to derive the ATC for a calibration parameter of the *B-Index* (average).

55 The estimations of these three specifications replicate the results by Bloom et al. (2002[10]), using updated data on business funded BERD and the user cost of R&D. While Bloom et al. (2002[10]) employ the user-cost of R&D in the regression analysis, and the *B-Index* as an instrument for the user cost of R&D; this study uses the *B-Index* as the policy variable. One can interpret the approach of this paper as the reduced-form approach of Bloom et al. Another difference between Bloom et al. (2002[10]) and this paper is that their analysis is confined to the manufacturing sector while this paper employs total business-funded R&D as dependent variable.

56 Instruments should be valid, i.e. correlate with the endogenous and not with the dependent variable; and strong, correlation is strong with the endogenous. The tables report statistics on the quality of the instrument set. The Kleibergen-Paap Wald F that tests for weak instrument in the presence of robust standard errors is reported. Critical values for the Kleibergen-Paap rk test are not tabulated but can be compared to the Stock-and-Yogo critical values; or else the rule-of-thumb that states that the F-statistic should be higher than 10 for weak identification issues not to be a problem can be used (Baum, Schaffer and Stillman, 2007[40]). The Anderson-Rubin Wald test tests for the significance of the endogenous regressors and the overidentifying restrictions of the instruments. The test for underidentification, in this case the Kleibergen-Paap rk LM test, tests for the correlation of the instruments with the endogenous regressor. Failure to reject the null indicates that the smallest canonical correlation of the endogenous with the instrument set is nonzero. The Hansen J test provides the robust version of the Sargan statistic of overidentification. A rejection of the null is

generally accepted to cast doubts on the validity of the instruments. Residuals have been tested for stationarity and correlation (reported for main specifications).

57 A specification of these regressions in intensities, i.e., as a percentage of GDP is presented in **Table D.1** for robustness.

58 Further checks available in **Annex D** (**Table D.2**) show that when confining the analysis to countries with permanent provision of R&D tax incentive support throughout 2000-16, the elasticity of business funded BERD to the *B-Index* remains statistically significant and has a similar, size of -0.13 in the short-run and 1.14 in the long-run.

59 Long-term interest rates are expressed in real terms removing the impact of inflation.

60 These results are available from the authors upon request.

61 The residuals of the specifications in columns (2) and (3) pass the test for stationarity and autocorrelation, indicating no spurious correlation among the variables. The test statistic for the Fisher unit-root panel of the residuals of specifications (2) and (3) of **Table 5** with its corresponding p-value are: Z=-4.72 (0.00) and Z=-5.79 (0.00). The test of autocorrelation also rejects the null of autocorrelation on the residuals with a p-value 0.37 and 0.29 respectively.

62 These are defined in the econometrics literature as “compliers” (Imbens and Angrist, 1994[45]; Angrist, Imbens and Rubin, 1996[46]).

63 Gross fixed capital formation (GFCF), is a formal statistical notion of “investment” that is defined as the acquisition of produced assets (including purchases of second-hand assets), including the production of such assets by producers for their own use, minus disposals. The relevant assets relate to assets that are intended for use in the production of other goods and services for a period of more than a year. The term "produced assets" means that only those assets that come into existence as a result of a production process are included. It therefore does not include, for example, the purchase of land and natural resources. For more details, see https://data.oecd.org/gdp/investment-gfcf.htm

64 Business sector GFCF comprises GFCF in all industry sectors (ISIC rev4), excluding public administration and defence, compulsory social security, education, human health and social work activities, arts, entertainment and recreation, other service activities, activities of households as employers, undifferentiated G&S-producing activities of households for own use, and activities of extraterritorial organizations and bodies.

65 Point estimates give information on the central estimate, i.e. ‘best guess’; while standard errors give an indication of the degree of (im)precision attached to the derived estimate. The standard errors have been derived using the delta-method.

66 The estimates for tax support and direct funding are also fairly stable to the choice of the statistical moments (weighted mean and median vs. unweighted mean) chosen for calibration purposes (**Table D.6**). While this holds true also for the *B-Index* based estimates, the incrementality ratios based on GTARD exhibit a greater sensitivity to the type of calibration parameter as a result of the skewedness of the business funded BERD to GTARD ratio that elasticities are multiplied with (Method 2).As a further robustness check, the additionality ratios were also estimated at the median value. The results are qualitatively similar.