Corporate Effective Tax Rates for R&D

The case of expenditure-based R&D tax incentives

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Abstract

R&D tax incentives have become a widely used policy tool to promote business R&D. How do they shape firms' incentives to invest in R&D? This paper contributes a methodology to construct forward-looking effective tax rates for an R&D investment that reflect the value of expenditure-based R&D tax incentives. The new OECD estimates cover 48 countries and consider the case of large profitable firms, accounting for the bulk of R&D in most economies. The results provide new insights into the generosity of R&D tax incentives from the perspective of firms that decide on whether or where to invest in R&D (extensive margin) and the level (intensive margin) of R&D investment. The generosity of the favourable tax treatment of R&D is shown to vary at the intensive and extensive margins, highlighting differences in countries' strategies to support R&D through the tax system.

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Executive summary

Innovation is recognised as a key driver of productivity and long-term growth. It is also instrumental in responding to societal and economic challenges, including those posed by the COVID-19 pandemic. Due to various failures in the market for research and development (R&D), businesses are likely to underinvest in R&D relative to the socially optimal level, in the absence of government intervention (OECD, 2015[1]; Hall, 2019[2]). To foster business R&D investment and innovation, governments adopt a mix of various financial and non-financial measures. Financial support can take the form of direct government funding (e.g. R&D grants, government procurement of R&D services) or of tax incentives that grant preferential treatment to R&D expenditures or to the income derived from R&D and innovation. In OECD countries, expenditure-based R&D tax incentives are the most favoured policy instrument, representing 55% of total government support for business R&D, or around USD 60 billion, in 2018 (OECD, 2021[3]).

The role of R&D tax incentives within the business innovation support policy-mix varies across countries, with most countries balancing both direct and indirect forms of financial support (OECD, 2021[3]). Direct funding typically represents a more discretionary and selective form of support, allowing governments to fund specific areas of research that are considered to offer high social returns. Tax incentives, on the other hand, are in principle available to all firms carrying out R&D subject to some pre-defined rules. Generally, this makes them easier and less costly to administer than direct support measures, although administration and monitoring costs could still be substantial.

Expenditure-based R&D tax incentives aim at increasing R&D activities by lowering their after-tax cost. The design of these provisions varies widely across countries, making a direct assessment and comparison of the tax benefits derived from R&D tax incentives difficult. Compounding this challenge, the globalisation of the economy has made the fragmentation of R&D activities possible (Galindo-Rueda et al., 2018[4]) by offering firms more flexibility to choose where to locate their R&D functions. This development may strengthen countries' efforts to attract R&D through policy, including tax policy, thereby further raising the importance of tax policy indicators that allow for an assessment of the cost of R&D that firms face when making R&D investment decisions.

Building on the effective tax rate (ETR) framework of Devereux and Griffith (2003[5]), this paper develops a methodology to analyse the effect of expenditure-based R&D tax incentives on firms' effective tax rates, taking countries' baseline tax system, i.e., the tax treatment of non-R&D investments, as a benchmark. This extended framework of ETRs for R&D considers a single hypothetical R&D investment with a fixed cost structure where only the baseline tax treatment and preferential tax treatment of R&D varies across countries.

The extended framework is applied to derive two sets of synthetic indicators that summarise the impact of all tax provisions (bases and rates) on firms' tax liability when undertaking R&D investments. The first is the cost of capital for R&D. It measures the required rate of return that a firm would need to break-even after tax, i.e. to yield zero economic profit. This indicator is used to compare decisions at the *intensive* margin, i.e. how much to invest in R&D at any given location. The second is the effective average tax rate (EATR), which measures the average tax liability on a profitable investment. This indicator is used to compare decisions at the *extensive* margin, for instance, where (i.e. in which jurisdiction) to locate an R&D site.

The two indicators – the cost of capital and the EATR for R&D – are conceptually linked to the established B-Index indicator, the tax component of the cost of capital, and build upon the same modelling of R&D tax incentives. However, they complement and extend the B-Index indicator in two important ways. First, by accounting for additional costs and taxes that firms face when evaluating R&D investments at the intensive margin; and second, by capturing decisions that refer to the extensive margin, such as the R&D location choices of multinational enterprises (MNEs).

The first estimates for 2019, presented in this paper, show how expenditure based R&D tax incentives affect the cost of capital and EATRs of large profitable firms in 48 countries. Based on headline tax credit/allowance rates, they provide an upper bound of the generosity of R&D tax relief. The preferential treatment for R&D *within* countries is measured by the reduction in the cost of capital or the EATR for the R&D investment against a comparable investment that does not qualify for relief. This comparison isolates the preferential treatment provided to R&D by removing the impact of baseline provisions available to other investment types. The results suggest that R&D tax incentives reduce the cost of capital on average by 3.5 percentage points and EATRs by 8.8 percentage points among OECD countries that offer R&D tax incentives in 2019. *Across* country comparisons show that the most favourable tax treatment provided to R&D differs at the intensive and extensive margins, measured by the cost of capital and EATR for R&D respectively. This result suggests that some countries offer greater incentives for the (re)location of R&D investment while others provide a greater incentive for existing firms already carrying out R&D activities in the country to expand their R&D investments. This study also investigates the sensitivity of results to the use of different shares of current and capital expenditure and the use of different private rates of return to R&D.

This variation in the generosity of R&D tax support can be attributed to policy choices and the availability of other support measures among other factors. A seemingly modest generosity of tax relief might simply reflect a country's preference to use direct funding to promote business R&D. Furthermore, the generosity of tax treatment of R&D, as measured by the cost of capital, EATR or B-Index, may not necessarily reflect one to one the actual cost of R&D tax relief incurred by countries (Appelt, Galindo-Rueda and González Cabral, 2019[6]) or permit any direct conclusions about the effectiveness of tax incentives in stimulating business R&D. Several factors, alongside tax and direct support measures, are considered to be important in the development of an environment that is conducive to R&D and innovation. This includes the availability of a skilled workforce, stable macroeconomic and regulatory conditions, competition and openness to trade, and policies that help overcome various barriers to innovation (e.g., regulatory barriers to competition or insufficient human capital) (Andrews, Criscuolo and Menon, 2014[7]; OECD, 2015[1]; Bloom, Van Reenen and Williams, 2019[8]).

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1. Introduction

1. Innovation is a key driver of productivity and long-term growth and a key vehicle to overcome social and economic challenges, as has been demonstrated in the face of the current global COVID-19 pandemic (Arjona, 2020[9]; OECD, 2020[10]; OECD, 2021[11]). Governments seek to strengthen business R&D investment and innovation through financial and non-financial support measures. Financial support can take the form of direct government funding (e.g. public procurement, grants) or indirect support through the tax system in the form of tax incentives for R&D expenditures.[1]

2. Over the last decade, R&D tax incentives that grant preferential treatment to R&D expenditures have gained ground as policy instruments to support business innovation in OECD countries,[2] representing 55% of total government support granted in 2018 compared to 36% in 2006 (OECD, 2021[3]). This proliferation in the use of R&D tax incentives can be linked to several factors (Appelt et al., 2016[12]; OECD, 2021[11]), including the reduced scope for discretionary measures on the side of public authorities. Typically, this ensures that tax incentives are more likely to comply with competition and international trade rules (OECD, 2014[13]) and are less costly to implement compared to direct funding measures, although administration and monitoring costs might still be non-trivial.

3. Since 2007, the OECD has continuously worked to extend the international evidence on R&D tax incentives through indicators (OECD, 2021[3]) and policy analysis (Appelt, Galindo-Rueda and González Cabral, 2019[6]; OECD, 2020[14]; OECD, 2020[15]). The existing indicators, published in the OECD Corporate Tax Statistics and OECD R&D Tax Incentives databases (OECD, 2020[16]; OECD, 2021[3]), highlight trends in the magnitude of tax and direct support for business R&D and notional levels of R&D tax subsidies by firm size (SME, large firm) and profit scenario (profitable, loss-making). The latter can be derived based

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[1] Governments may also provide tax relief for the income derived from R&D and innovation, alone or in combination with expenditure-based tax incentives. Income-based tax incentives for R&D and innovation are beyond the scope of this report due to the lack of comprehensive and internationally comparable data on the design and cost of such incentives. Future work to be carried out as part of the new OECD KNOWINTAX project will aim to fill this evidence gap in collaboration with OECD and partner economies.

[2] In 2020, 33 out of 37 OECD countries offer tax support for R&D expenditures at central or subcentral levels. Switzerland does not provide expenditure-based R&D tax incentives at the central government level, however an optional R&D tax deduction at cantonal (subnational) level was introduced in 2020. The four OECD countries that do not offer expenditure-based R&D tax incentives in 2020 at central or subcentral levels are Estonia, Finland, Latvia and Luxembourg.

on the B-Index, a measure of the pre-tax income needed by a representative firm to break even on one monetary unit of R&D outlay (Warda, 2001[17]; OECD, 2021[3]). While measures of the marginal cost of R&D[3] are relevant for investment decisions at the intensive margin (i.e. how much to invest), they differ from the average cost of R&D that shape firms' investment decisions at the extensive margin (i.e. whether to invest in a particular location) such as the R&D location choices of MNEs.

4. The globalisation of the economy has made the fragmentation of R&D activities possible (Galindo-Rueda et al., 2018[4]) by offering firms more flexibility to choose where to locate their R&D functions. This development may strengthen countries' efforts to attract R&D through policy, including tax policy. In 2016, the top 2000 R&D investors represented over 90% of the total business R&D investment of OECD countries and seven selected economies[4] (Dernis et al., 2019[18]). Large companies typically account for the bulk of R&D in most OECD countries. This brings to the fore the importance of tax policy indicators that allow for an assessment of the cost of R&D that large firms such as MNEs face when making R&D investment decisions at the *extensive* margin (i.e. where to locate R&D). At this stage, the effect of R&D tax incentives on the R&D location choices of MNEs remains a relatively unexplored issue.

5. With a view to extending the existing set of R&D tax incentive indicators and facilitating policy analysis, the OECD Centre for Tax Policy and Administration (CTPA) and Directorate for Science Technology and Innovation (STI) launched a joint project to integrate R&D into the OECD's ETR framework. This joint project brings together two key areas of work. First, the measurement and modelling work of STI on expenditure-based R&D tax incentives (Appelt, Galindo-Rueda and González Cabral, 2019[6]; OECD, 2021[3]). Second, the modelling work of CTPA on forward-looking effective tax rates (Hanappi, 2018[19]; OECD, 2020[16]), which incorporates cross-country differences in the general tax system, including differences in corporate tax bases and rates.

6. This working paper presents the methodology adopted in integrating R&D into the ETR framework and synthesising the effect of expenditure-based R&D tax incentives on firms' ETRs, taking countries' baseline tax system (i.e., the tax treatment of non-R&D investments) as a benchmark and keeping the cost structure of the hypothetical R&D investment (i.e., the share of current and capital expenditure) fixed, in line with the average distribution of R&D costs in OECD countries. Two sets of synthetic indicators are derived based on this extended ETR framework that summarise the effect of R&D tax incentives and other corporate tax provisions (i.e. tax bases and tax rates) on the cost of R&D, considering the case of large profitable firms in 48 countries.[5] The first indicator is the cost of capital[6], based on Hall and Jorgenson (1967[20]), which reflects the reduction of a firm's tax liability resulting from an *extra* euro invested in R&D and can be used as indicator to compare decisions at the intensive margin, looking at the marginal case,

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[3] Measures of the marginal cost of R&D – the cost of capital, or of its tax component, the B-Index – have been extensively used in the literature to estimate the impact of R&D tax incentives on the level of business R&D investment. The existing evidence suggests that business R&D reacts to changes in the cost of R&D whereby the effectiveness of R&D tax incentives in stimulating R&D varies across different types of firms. For a review of the literature, see Larédo et al. (2016[51]), Appelt et al. (2016[12]) and Hall (2019[2]); and for the impact of taxation on innovation see Akcigit and Stantcheva (2020[52]).

[4] Argentina, People's Republic of China (hereafter 'China'), Romania, the Russian Federation, Singapore, South Africa and Chinese Taipei.

[5] This study covers 37 OECD countries, non-OECD EU countries (Bulgaria, Cyprus, Croatia, Malta, Romania) and six additional partner economies (Argentina, Brazil, China, the Russian Federation, South Africa and Thailand).

[6] Another indicator that is typically presented to analyse decisions at the intensive margin are effective marginal tax rates, which are based on the cost of capital. When estimates of the cost of capital are negative, which is typically the case in the presence of R&D tax incentives, the tax-inclusive EMTR is not well-defined. A tax-exclusive EMTR could alternatively be derived. However, since the cost of capital summarises the impact of taxation, this paper focuses on this measure as the key metric at the intensive margin. See Section 3.1.1. for a discussion of the linkages and derivations of these measures.

where the firm makes no economic profit. The second indicator is the effective average tax rate (EATR), based on Devereux and Griffith (2003[5]), which specifies the average tax liability that the firm faces on an R&D investment that makes an economic profit, a metric relevant for R&D investment decisions at the extensive margin.

7. The two new indicators – the cost of capital and the EATR for R&D - are conceptually linked to the B-Index, the tax component of the cost of capital, and rely on the same modelling of R&D tax incentives. However, they complement and extend the existing B-Index indicator in two important ways, by accounting for additional taxes associated with the R&D investment and providing a measure of the cost of R&D at the extensive margin. The first estimates for 2019, presented in this report, provide a cross-country comparative framework to assess the preferential treatment of current and capital expenditure that contribute to the R&D investment. Differences in the preferential treatment of R&D are assessed within and across countries. Within countries, by comparing the tax treatment of the R&D investment to a comparable non-R&D investment, which allows for the impact of R&D tax incentives to be isolated from the standard tax treatment that would apply to *all* types of investment. Across countries, by comparing the position of countries across measures of the cost of capital and the EATR.

8. This comparative framework facilitates a comprehensive assessment of how the tax system and R&D tax incentives more specifically reduce the cost of R&D within and across countries, considering R&D investments at both the intensive and extensive margin. While these estimates do not provide any direct evidence on the actual cost of R&D tax support incurred by countries and do not permit direct conclusions about the effectiveness of R&D tax incentives in stimulating business R&D investment (OECD, 2015[1]; Bloom, Van Reenen and Williams, 2019[8]), they represent an important step in building up a data infrastructure that can support further policy analysis directed at these questions. As indicators of the generosity of R&D tax support, they should be interpreted alongside direct support measures and other factors that shape the R&D and innovation environment of a country. Building upon the OECD ETR and R&D tax incentive modelling work and in collaboration with the OECD R&D Tax Incentive network, this paper contributes to the existing literature (Evers, Miller and Spengel, 2013[21]; Lester and Warda, 2014[22]; Evers, Miller and Spengel, 2015[23]; Bösenberg and Egger, 2017[24]) by providing recent estimates of ETRs for R&D that reflect the effect of R&D tax incentives on the cost of R&D in OECD countries and partner economies.[7]

9. The working paper is organised as follows. Section 2. provides a brief introduction to the use of expenditure-based R&D tax incentives in governments' business R&D support policy mix and summarises the main design features of expenditure-based R&D tax incentives. Section 3. provides an intuitive overview of the ETR framework and how R&D tax incentives may affect ETRs. Section 4. outlines the modelling of expenditure-based R&D tax incentives in the ETR framework. Section 5. covers the data and calibration parameters used in the analysis. Section 6. presents the results on effective tax rates for R&D investments and Section 7. concludes.

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[7] Evers, Miller and Spengel (2013[21]; 2015[23]) derive measures of effective tax rates and the cost of capital for R&D investments including both expenditure and income-based tax incentives, but with a particular focus on the latter. The estimates cover EU countries and countries in the European Free Trade Association with their most recent figures referring to the year 2014. Bösenberg and Egger (2017[24]) calculate estimates of the B-Index, the tax component of the user cost of capital for R&D, and the effective average tax rate incorporating expenditure-based R&D tax incentives for 106 countries for the period 1996-2012. Lester and Warda (2014[22]) provide estimates of the cost of capital for R&D in OECD countries and Brazil, Russia, India and China.

2. Tax incentives for R&D expenditures

2.1. An instrument in the business R&D support policy-mix[8]

10. The economic argument for public support for business R&D rests on the notion that, in the absence of support, there would be an underinvestment in R&D relative to the socially optimal level (OECD, 2015[1]). The imperfect appropriability of the returns to innovation due to the presence of spillovers, the risky and uncertain nature of R&D and the higher cost of financing of these investments, which is often more relevant for young firms and SMEs, are among the reasons often cited in the literature (Arrow, 1962[25]; Romer, 1990[26]; Aghion and Howirrt, 1992[27]; Hall and Lerner, 2010[28]; Hall, 2019[2]).

11. To support business R&D, governments can offer direct financial support for R&D and innovation via grants or public procurement of R&D services; or they can indirectly strengthen the incentives for firms to invest via the tax system. These two types of policy instruments are different in the way they are administered, the type of market failures they address and the different types of R&D they encourage (OECD, 2015[1]; Appelt et al., 2016[12]). Direct support measures such as grants can be directed to research areas or projects that governments consider to offer high social returns but that may be more risky, for instance basic research (Akcigit, Hanley and Serrano-Velarde, 2013[29]; OECD, 2021[11]). While this type of targeting may help minimise the amount of "subsidised" R&D that would have been undertaken even in the absence of support (deadweight), it also makes funding dependent on the discretionary funding decisions of government bodies. Effective targeting may come at the cost of significant financial and administrative resource requirements.

12. Tax incentives in turn are granted to all firms that qualify for a set of pre-defined conditions and leave the selection of R&D projects to firms. This makes them less discretionary and typically easier and less costly to administer. However, depending on the design of the tax provisions, they may also lead to significant deadweight losses if tax incentives are granted to R&D that would have taken place in the absence of support (Appelt et al., 2016[12]; Hall and Van Reenen, 2000[30]). The non-discretionary nature of tax incentives may also limit the scope for identifying and supporting projects with higher social returns (OECD, 2021[11]) and assessing the veracity of R&D tax incentive claims, i.e., identifying cases where existing non-R&D activities are relabelled as R&D poses difficulties for tax administrations (Guceri, 2018[31]).[9]

13. In practice, most OECD countries combine direct funding and tax instruments in their policy-mix, but to different extents (OECD, 2021[11]; OECD, 2021[3]). Tax support for R&D expenditures represent over 80% of total support in Australia, Italy, Japan, Portugal and Colombia in 2018, while they represent less than 20% of the support granted in countries such as Sweden, New Zealand and Mexico. This highlights the importance of taking account of both tax and non-tax support measures in order to form an accurate picture of government efforts to support business R&D.

14. This paper places the focus on the use of the tax system to incentivise business R&D, particularly through the use of R&D tax incentives that provide advantageous tax treatment to innovation inputs (R&D expenditures). R&D tax incentives can also offer tax relief to innovation outputs (income from the

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[8] This section seeks to provide the reader with a quick overview of the rationale for support and the role of tax incentives as an instrument in governments' policy mix to support business R&D and innovation, with the aim of situating the use of this instrument. For a more in-depth discussion of these topics, the reader is invited to consult the following references (OECD, 2015[1]; Appelt et al., 2016[12]; Bloom, Van Reenen and Williams, 2019[8]; Hall, 2019[2]; OECD, 2020[14]). Governments can also affect innovation through non-financial means, see OECD (2021[11]).

[9] Countries differ in the way tax support is administered, with some having in place pre-approval of R&D projects or claims and accreditation, having features that are functionally equivalent to grants.

exploitation of intellectual property). However, while policy-relevant, the analysis of income-based tax incentives is left for future work.[10]

2.2. Key design features

15. There is substantial variation in the design of R&D tax incentives across countries, and the generosity of these provisions is tightly linked to their design. Table 1 provides a summary overview of the key design features of expenditure-based R&D tax relief provisions.

16. Unlike most traditional capital investments, the composition of spending that feeds into R&D investment reflects a mix of current and capital expenditure, with the former playing a much more prominent role (see Section 5.1.). Across countries, there exists variability in the type of expenditure—current or capital—that is eligible for preferential tax treatment. R&D tax incentives generally offer support for current expenditure (labour costs and other current expenditure, e.g. materials), including payments for subcontracted R&D in some cases. Some countries also offer tax relief for capital inputs (e.g. machinery and equipment, buildings, software) used in the context of an R&D investment. When available, it generally applies to the depreciation rather than acquisition cost of the asset. R&D investments differ to some extent in the share of current and capital expenditure used, which, paired with the heterogeneity in the eligibility of R&D expenditure, may create differences in the tax treatment across investment projects.

Table 1. Key design features of expenditure-based R&D tax incentives

Feature	Description	
Eligible expenditure	Current expenditure	**Includes:** – Labour – Other current expenditure: payments for R&D services provided by consultants and other third parties, payments for other services, contributions to R&D carried out with third parties (e.g. collaboration agreements), materials and other consumables and overheads.
	Capital investment	**Type of asset:** – Tangible assets – Non-residential structures
		Eligible cost: – Acquisition cost – Depreciation
Tax base against which relief is granted	– Corporate Income Tax – Corporate Income Tax and other taxes, e.g. local taxes – Payroll taxes or social security contributions	
Form of tax relief	– Tax credit – Tax allowance – Exemption – Accelerated or enhanced depreciation	
Type of instrument	– Volume-based: tax relief applies to the full extent of eligible R&D. – Incremental: tax relief applies to eligible R&D above a certain threshold. – Hybrid: Contains a volume-based and incremental component.	
Taxability	– Taxable – Non-taxable	
Limitations to tax benefits	– Ceilings that establish a cap to the amount of eligible R&D expenditure that qualifies for relief or to the amount of tax benefits that can be granted under the scheme. – Floors that establish a minimum amount of eligible R&D expenditure to qualify for relief. – Thresholds that typically define a cut-off above which the amount of R&D tax relief is	

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[10] Hereafter, when the paper refers to R&D tax incentives, it is referring to expenditure-based R&D tax incentives, unless specified otherwise.

	typically reduced.
Treatment of unused claims	– Carry-over provisions of unused tax benefits: Carry-forward or carry-backward – Refundability of unused credits

Note: This table summarises key design features of expenditure-based R&D tax incentives. A more comprehensive summary table of the main R&D tax incentive design features for OECD and partner economies is available in OECD (2020[32]) .
Source: OECD Secretariat.

17. R&D tax incentives can provide relief against different tax bases. The most common base against which R&D tax incentives provide relief is the corporate income tax (CIT) base. In some countries, it is not limited to the CIT base and tax benefits can also be redeemed against other types of taxes, e.g. regional taxes in the case of Italy (IRAP[11]). Relief can also be provided with respect to social security contributions (SSCs) or payroll taxes to provide a subsidy to R&D labour costs and other qualifying R&D expenditure. The latter are thought to provide a subsidy to the firm that is independent of the profit or loss position and thereby more likely to ease financial constraints that young firms and SMEs investing in R&D typically face.

18. Tax incentives can take the form of R&D tax credits, allowances, exemptions, and accelerated or enhanced depreciation provisions for R&D capital inputs[12]. While tax credits directly reduce the tax liability of the firm, tax allowances reduce taxable income and their value is therefore a function of the CIT rate. Partial or full tax exemptions typically apply in the context of wage-related tax incentives. Accelerated depreciation provisions allow the value of the asset used for R&D to be written-off for fiscal purposes in a shorter period than would be allowed if it were for non-R&D use. Accelerated depreciation does not increase the value of the asset, i.e. the firm can only write-off 100% of the acquisition cost, but can do so faster than would otherwise be the case. In certain countries, the tax incentive increases the value of the asset that can be written-off for fiscal purposes if used for R&D, e.g. the firm can write-off 130% of the value of the asset. This is termed enhanced depreciation.

19. R&D tax relief may apply to the full amount of eligible R&D or only the amount that exceeds a certain base amount. The first type of incentive is referred to as volume-based tax incentives; the second as incremental. For incremental R&D tax provisions the base amount can be fixed or based on a rolling average of qualifying R&D expenditure in the previous “x” years. One of the main reasons to use an incremental scheme is to ensure that the subsidy is linked to additional R&D, minimising the availability of tax incentives for R&D that would otherwise have been undertaken in the absence of support. Some countries offer a hybrid R&D tax incentive scheme, with a volume and an incremental component.

20. Tax benefits may also be subject to taxation. In some cases, tax benefits may be treated as taxable income, i.e., the amount of expenditure that qualifies for the baseline deduction (e.g. the amount of current expenditure immediately expensed) is reduced by the amount of the tax benefit. In other cases, the baseline deduction of qualifying expenditure needs to be completely foregone in order to enjoy the tax benefits.

21. In order to maintain budgetary control and ensure a more equitable distribution of tax benefits, countries may limit R&D tax benefits via ceilings, thresholds or floors. Ceilings may apply to eligible expenditure or to the amount of tax relief, or both. While floors establish a minimum level of R&D

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[11] Imposta regionale sulle attività produttive.

[12] The term acceleration is used in the literature when the tax system allows a capital investment to be depreciated faster than its economic depreciation rate. This comparison informs the degree of generosity of the tax system. In cases where the tax system allows faster (slower) recovery of the cost of the investment than the actual economic depreciation, this is referred to as fiscal acceleration (deceleration). However, in the context of this paper, accelerated provisions *for R&D* is used when the tax system provides preferential treatment to the capital asset when it is used in the context of an R&D vis-à-vis a non-R&D investment, regardless of the comparison with the economic depreciation rate.

expenditure that determines tax relief eligibility, thresholds may define the amount of qualifying R&D expenditure (incremental incentives) or applicable tax credit or allowance rates in the case of threshold-dependent rates.

22. Special provisions typically exist for firms that cannot fully utilise their tax benefits due to insufficient tax liability. This can take the form of carry-over provisions of unused tax benefits (carry-forward or carry-back); or refunds (cash-payments) of unused claims. The design of R&D tax incentives may also entail preferential tax treatment (e.g. enhanced rates or refundability terms) to certain types of firms such as SMEs, start-ups or young firms; or activities, i.e. R&D collaboration. The preferential treatment offered to SMEs and young firms is typically justified on the grounds that they are more likely to be affected by credit constraints.

3. ETRs for R&D: A general framework

3.1. An intuitive look into the general ETR framework

23. Taxation is one among several factors affecting firms' decision to invest in R&D (Akcigit et al., 2018[33]). When making investment decisions, firms generally consider several margins. In particular, the decision of how much to invest in a given project is different from the decision on whether or where to invest, and the metrics that influence these investment choices may vary. While other decision margins are also relevant, e.g. the choice of ownership structures or sources of finance, the analysis presented in this paper focuses on the impact of R&D tax incentives for investment at the extensive and intensive margin.

24. Decisions that target the intensive margin—how much to invest in R&D in any given location—refer to the *marginal* investment, i.e. an investment that yields zero-profit after tax. Two connected indicators to analyse the impact of taxation on the marginal investment are the user cost of capital, which represents the minimum pre-tax rate of return required to make the investment worth undertaking; and, derived from it, the effective marginal tax rate (EMTR), which indicates by how much taxation affects the cost of capital with respect to the real interest rate. A third indicator, which is well-established in the R&D literature, is the B-Index. The B-Index represents the tax component of the user cost of capital and accounts for expenditure-based R&D tax incentives that reduce the cost of R&D to firms (see Warda (2001[17]) and Box 1 in Appelt et al. (2019[6])). In this paper, Box 1 provides an intuitive discussion of the three indicators.

25. In a world marked by the fragmentation of global value chains, firms are able to relocate their R&D functions to benefit from the tax regimes and other factors offered by different countries. In this context, firms make discrete choices, e.g. whether to locate R&D functions in Country A or Country B. These decisions will ultimately be based on the post-tax economic profits that the project is expected to deliver when undertaken in either of the available locations. This means that the investment is *inframarginal*, i.e., an investment that yields economic profits over and above the normal return that could be obtained from an alternative use of the same funds. In this case, the effective average tax rate (EATR) is the relevant tax policy indicator.

26. The cost of capital and the EMTR, on one hand, and the EATR on the other hand, should be considered as complementary indicators, as each is associated with a different decision margin. For instance, a firm relocating their R&D production will look first at the effective average tax rate to choose the location of an R&D laboratory. Conditional on the choice of its location, the EMTR will determine the scale of investment, e.g., the number of researchers to hire or the size of the R&D laboratory.

27. This section discusses effective tax rates for marginal and inframarginal projects with the help of graphic illustrations. The microeconomic investment model behind these representations is based on

Devereux and Griffith (2003[5]) and Creedy and Gemmell (2017[34]).[13] Annex A summarises selected relevant formulae.

3.1.1. A marginal investment

28. Standard investment theory posits that a profit-maximising firm will increase investment until the marginal after-tax return from the investment equals the marginal after-tax cost of the project. Accordingly, when faced with the choice of how much to invest in R&D in a given country, the firm will be interested in the break-even point above which no more profits are attained from investing incrementally. The cost of the project is the cost of funds, i.e. the interest rate paid on the loan if financed by debt or the opportunity cost of using the funds in the next-best available investment if financed by retained earnings or new equity.

29. The minimum pre-tax rate of return necessary for the investor to cover the cost of the investment and any taxes associated with it, without making any economic profits, is defined as the user cost of capital. In principle, all projects that earn a pre-tax return larger than the user cost of capital are economically viable projects. The user cost of capital is a key component in the derivation of effective tax rates. The EMTR, which is the tax rate faced by the investor on a marginal project, is based on the user cost of capital.

30. Figure 1 outlines the case of a marginal investment financed by retained earnings, considering neither inflation nor personal income taxation. The x-axis represents the amount of capital the firm invests in dollar amounts; the y-axis displays the real rate of return and the cost of capital. The plotted downward-sloping line in Figure 1 represents the marginal revenue product curve (MRP_K). This curve represents the capital investment the firm is willing to make at each rate of return (or marginal revenue product).[14] Given this theoretical setting, the firm will increase investment until the revenue obtained from an extra unit of capital equals its cost. This occurs at the intersection of the cost of capital (i.e., the cost of the marginal investment) and the MRP_K curve.[15] The user cost of capital, $\tilde{p}$, is defined in this section net of economic depreciation. This means that, using a geometric economic depreciation rate δ, the gross user cost of capital is defined as $\tilde{p}^{gross} = \tilde{p} + \delta$.

31. In the absence of taxation, a profit-maximising firm will increase investment until the return after depreciation obtained from an extra unit of capital equals the opportunity cost of the investment. Thus, in the absence of taxation, the user cost of capital, $\tilde{p}$, equals the real interest rate, r – see equation (1).[16] Investments with a rate of return below r would not be worth undertaking.

$$\tilde{p} = r \tag{1}$$

32. In Figure 1, the point where the cost of capital intersects the MRP_K (point a in the graph) defines the level of capital investment b. To the left of b, investment projects still have a rate of return higher than the cost of capital and therefore the firm still has the incentive to invest until point b where economic profits are exhausted. The firm has no incentive to invest beyond point b since the rate of return that these

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[13] The Devereux and Griffith model used to compute EATRs builds on a hypothetical two-period investment model. The firm invests one unit of R&D in the first period, the capital stock will consequently increase and a disinvestment at the end of the second period will revert the capital stock to the level prior to the one-period perturbation. With a more practical example, the firm buys an asset in year 1, the asset contributes to production and generates a return during that year, and then the asset is disposed of in year 2.

[14] Assuming decreasing marginal returns to capital, the return is expected to fall as the capital stock grows.

[15] This is the case of a competitive market where in equilibrium marginal revenue equals marginal cost.

[16] The Fisher equation establishes the link between the nominal interest rate, i, the real interest rate, r, and the inflation rate, π, as $(1+i) = (1+r)(1+\pi)$. Note that r in equation (2) captures the after-tax real interest rate.

investments yield would be lower than their cost. In that case, it would be more advantageous for the firm to invest in the next-best alternative.

33. In the presence of taxation, tax provisions such as fiscal depreciation or tax incentives lower the effective cost of the investment to the firm. Labelling A the net present value of allowances, that contain the impact of all tax provisions that reduce the cost of an R&D investment over its lifetime, the effective cost of the investment is given by $1 - A$. A profit-maximising firm will increase investment until the return after-tax and depreciation $(p + \delta)(1 - \tau) - \delta(1 - A)$ equals the effective cost of the investment after tax, $r(1 - A)$,

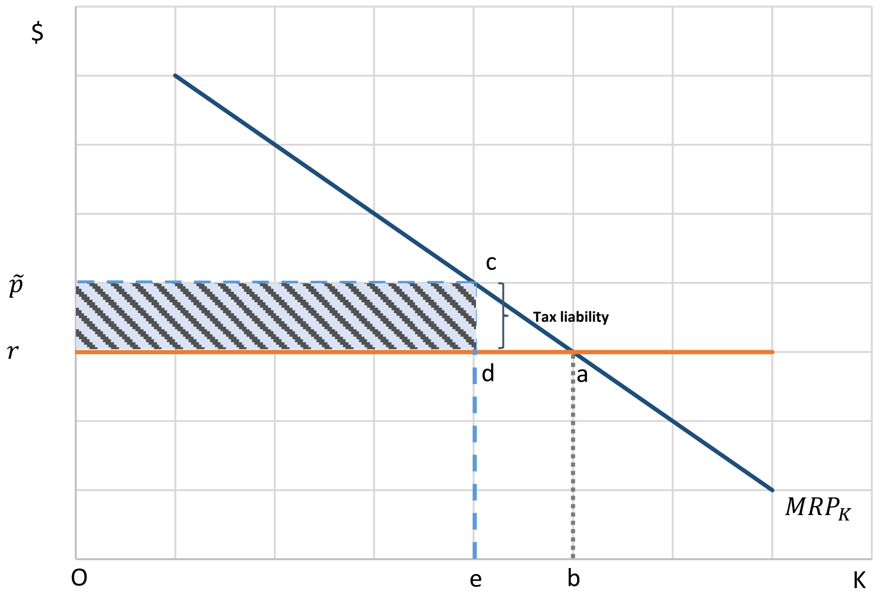
$$(p + \delta)(1 - \tau) - \delta(1 - A) = r(1 - A). \tag{2}$$

34. The user cost of capital, $\tilde{p}$, defines the pre-tax net rate of return that ensures that the return after tax from the marginal investment equals the real rate of interest r. Solving for the user cost of capital yields:

$$\tilde{p} = \frac{(r + \delta)(1 - A)}{1 - \tau} - \delta = (r + \delta)(\,B\text{-}Index) - \delta. \tag{3}$$

35. The user cost of capital has a tax and an economic component. The tax component of the cost of capital of an R&D investment is known as the B-Index, i.e. $B\text{-}Index = {}^{1-A}\!/_{1-\tau}$. (cf. Box 1 in this paper, Warda (2001[17]), and Box 1 in Appelt et al. (2019[6])).

Figure 1. The case of a marginal investment and the effect of taxation



Source: OECD Secretariat adapted from Creedy and Gemmell (2017[34]).

36. In the stylised case of Figure 1, taxation requires firms to attain a higher pre-tax return to break-even as they also need to offset taxes.[17] When taxation is in place, therefore, the user cost of capital $\tilde{p}$ defines the new level of capital investment, e in the chart. The area between the user cost of capital and the real interest rate reflects the tax liability on the marginal investment, i.e. $\tilde{p}cdr$ in Figure 1.[18]

37. The pre-tax return of the marginal investment given by the area $\tilde{p}ce0$ Figure 1 splits into two components:

i. The opportunity cost of capital in the absence of taxation given by the real interest rate, i.e. area $rde0$.

ii. The extra pre-tax return required in the presence of taxation to yield an after-tax rate of return on the investment equal to the real interest rate (i.e. area $\tilde{p}cdr$). This area represents the tax liability on the marginal investment.

38. Figure 1 allows for a straightforward definition and interpretation of the EMTR. The EMTR captures the difference between the before-tax rate of return and the real interest rate for a marginal investment. Two representations of the EMTR, depending on the normalisation of the tax liability are possible. The tax inclusive EMTR is obtained by dividing the tax liability of the marginal investment by the user cost of capital, i.e., $EMTR^I = (\tilde{p} - r)/\tilde{p} = \tilde{p}cdr/\tilde{p}ce0$. This is the EMTR reported in Devereux and Griffith (2003[5]) and used in the Corporate Tax Statistics database (OECD, 2020[16]). An alternative representation of the EMTR can be derived by dividing the tax liability $(\tilde{p} - r)$ by r, yielding the tax exclusive EMTR, i.e., $EMTR^E = (\tilde{p} - r)/r = \tilde{p}cdr/rde0$. The advantage of $EMTR^I$ is that it offers a better comparability with the statutory CIT rate, as the $EMTR^I$ and EATR will equal the statutory CIT rate when the fiscal depreciation of the asset equals economic depreciation. The $EMTR^E$ however represents a more suitable measure when the cost of capital $\tilde{p}$ is equal or close to zero, e.g. in the presence of very generous tax incentives. The choice of one parameter to another will depend on the question of analysis.

Box 1. Three indicators to assess the preferential treatment provided to R&D

The B-Index is a well-established indicator in the R&D literature. It captures the extent to which different tax systems reduce the effective cost of R&D. When a firm invests in R&D, the cost of investing is reduced by the availability of tax deductions, which are typically higher than those available to non-R&D investments, due to the presence of tax incentives for R&D expenditures. If a firm that invests one unit in R&D can deduct an amount equal to A, the effective cost of the R&D investment is ultimately $1 - A$. The effective cost, $1 - A$, normalised by the net-of-tax statutory CIT rate yields the B-Index (Warda, 2001[17]; OECD, 2021[3]).

The user cost of capital is an indicator that measures the return that a firm needs to realise on an investment before tax to offset all costs and taxes that arise from the investment, making zero economic profit (Hall and Jorgenson, 1967[20]). While the tax system may reduce the effective cost of the upfront investment, as discussed above, the firm also considers the taxation of the return, which could potentially benefit from preferential treatment or be affected by other tax provisions (e.g., taxation at the shareholder level relating to personal income or capital gains). Also, the asset in which it invests loses value over time, and this is another cost of the firm that needs to be taken into account when

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[17] Note that this does not always need to be the case. If tax provisions are very generous, the cost of capital can fall below the real interest rate making investments profitable that were, in fact, unprofitable before taxation. In this case, the pre-tax rate of return required with taxation would be lower than under no taxation. See Section 3.2.

[18] Note that the model considers one unit of investment. Therefore, the equations outlined in this section map into the areas defined in the graphs.

assessing the return to investment. The firm compares the opportunity cost of capital, i.e. what it would obtain from investing in the next-best possible alternative, with the return to be obtained from the project, accounting for all tax liabilities and costs. The user cost of capital is the pre-tax rate of return that equalises the two alternatives. It can also be interpreted as the minimum pre-tax rate of return that an investment needs to yield in order to be profitable.

The effective average tax rate (EATR) is an indicator that summarises the impact of taxation on investments that yield positive economic profits (Devereux and Griffith, 2003[5]). Unlike the previous indicators, the EATR considers taxation in the presence of economic profits. When choosing between competing projects, the firm will choose the investment that yields the highest economic post-tax economic profits.

The cost of capital, the B-Index and the EATR are conceptually directly linked and rely on the same modelling of R&D tax incentives. As indicators of the cost of R&D for a marginal unit of R&D outlay, the B-Index and cost of capital are used in the economic literature to assess firms' R&D investment decisions at the intensive margin. The B-Index offers a way of comparing the generosity of R&D tax incentives in reducing the upfront investment cost of an R&D investment. By isolating the tax component in the cost of capital (abstracting from financing decisions), it does not require assumptions on the depreciation rate of R&D, which is typically difficult to measure, and directly displays the variation in the tax treatment induced by R&D tax incentives. Accounting for additional costs and taxes relevant to the R&D investment, the cost of capital complements and extends the B-Index indicator. Since the cost of capital can in principle account for a variation in economic depreciation across assets, it also facilitates the analysis of different types of R&D projects. Finally, the cost of capital is also a stepping-stone into the calculation of the EATR.

While the B-Index and the cost of capital are relevant to assess investment decisions at the *intensive margin* (how much to invest in R&D), the EATR is relevant for the assessment of investment decisions at the *extensive margin* (where or whether to invest in R&D). Altogether the three indicators offer a complementary view to assess the impact of taxation on firms' R&D investment decisions.

3.1.2. An inframarginal investment

39. EATRs are relevant when a firm is deciding between mutually exclusive projects that earn an economic profit. In this case, investment decisions are driven by the relative magnitude of economic profits associated with each project. Assuming that not all projects can be undertaken simultaneously, the preferred project will be the one that yields the highest post-tax economic profits.

40. Figure 2 illustrates the difference between a marginal and inframarginal project. To capture the fact that inframarginal projects earn an economic profit, the pre-tax rate of return is assumed to be higher than the user cost of capital, i.e. $p > \tilde{p}$.[19] If the firm requires the project to yield a pre-tax rate of return, p, the level of investment is given by point i. The blue-shaded box ($pfhr$) represents the pre-tax economic profits on the investment.

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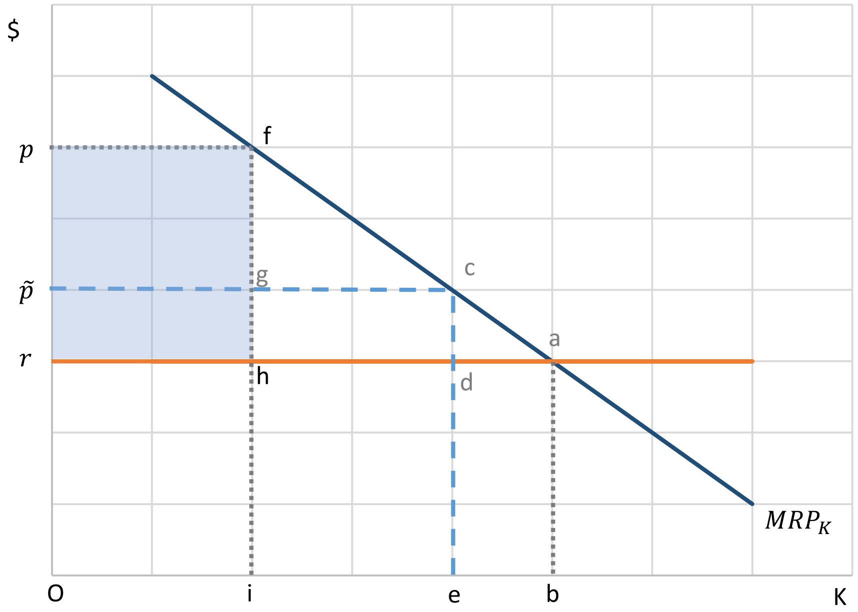
[19] The user cost of capital is the rate of return at profit-maximisation that therefore identifies the marginal investment, i.e. zero economic profit.

Figure 2. The case of an inframarginal investment



Source: OECD adapted from Creedy and Gemmell (2017[34]).

41. As in the case of the marginal project, the calculation of EATRs can be illustrated graphically. EATRs measure the average tax payment faced by an investor on a profitable investment earning a pre-tax rate of return of p.[20] The numerator of the EATR identifies the tax liability on the profitable investment by comparing the net present value of the economic profits before and after tax, R^* and R respectively. The denominator, the pre-tax total income stream of the project (net of depreciation), serves to scale this difference in order to construct an implied tax rate, where r, the real interest rate, is used for discounting.[21]

42. The EATR can be written as,

$$EATR = \frac{R^* - R}{p/(1+r)}. \tag{4}$$

43. Figure 3 helps illustrate the calculation underlying equation (4). The economic profit in the absence of taxation, R^* in equation (4), is given by rectangle $pfhr$. The post-tax economic profit, R in equation (4), is given by the area $mjg\tilde{p}$ (see Figure 3**)**.

44. The difference between the economic profit without and with taxation, R^* and R, determines the total tax liability of the firm. As shown in Figure 3, the total tax liability of the firm can be decomposed into

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[20] The EATR can also be interpreted as producing a distribution of tax rates for projects with different profitability. The basis for the methodology for computing effective tax rates outlined in this paper relies on a hypothetical investment that earns a profit following Devereux and Griffith (2003[5]).

[21] Another choice of normalising the rate would be scaling using pre-tax economic profits, R^*. However, this would not allow for the EATR to be defined in the cases where post-tax economic profits are equal to zero, hence the use of the discounted value of the income stream (net of depreciation) as normalising variable. The denominator, as the numerator, is discounted one-period. Scaling by p, rather than by $p - r$, implies using the total income rather than the economic profits, which makes the forward-looking rate more comparable to backward-looking effective tax rates.

two components: i) the tax liability arising from the marginal investment case (i.e. area $\tilde{p}ghr$); ii) the tax on the economic profit (i.e. area $pfjm$). In fact, equation (4) can be modified as just described to yield the following expression (taking into account the discounting of the economic profits to align the timing with the other terms in the equation).[22]

$$EATR = \frac{R^{*} - R}{p/(1+r)} = \frac{\frac{p-r}{1+r} - \frac{(p-\tilde{p})(1-\tau)}{1+r}}{p/(1+r)} = \frac{\tilde{p} - r + \tau(p-\tilde{p})}{p}. \tag{5}$$

45. This representation of the EATR maps into Figure 3 showing in the numerator the tax liabilities defined by the striped areas $\tilde{p}ghr$ and $pfjm$ in the graph While the first element of the numerator, $\tilde{p} - r$, is the same as in the case of a marginal investment, the second element captures the taxation of economic profits, $(p - \tilde{p})$, at the statutory rate, τ.The denominator represents the total pre-tax return defined by the area, $pFIO$.

46. As can be seen from the graphical representation, the case of the inframarginal investment builds on that of the marginal investment. In contrast to the case of the marginal project, Figure 3 illustrates the case where economic profit arises. Accordingly, the total pre-tax return of an inframarginal investment given by the rectangle $pFIO$ in Figure 3 now splits into four components:

i. The opportunity cost of capital in the absence of taxation given by the real interest rate (i.e. area $rHIO$ in the graph).

ii. The extra pre-tax return (i.e. area $\tilde{p}ghr$) required in the presence of taxation to yield an after-tax rate of return on the investment equal to the real interest rate. This area represents the tax liability on the marginal investment.

iii. The tax liability on the economic profit from the inframarginal investment (i.e. area $pfjm$ in the graph), where the (pre-tax) economic profit in the presence of taxation[23] is given by the area $pfg\tilde{p}$ in the graph.

iv. The after-tax economic profit given by area $mjg\tilde{p}$ in the graph.

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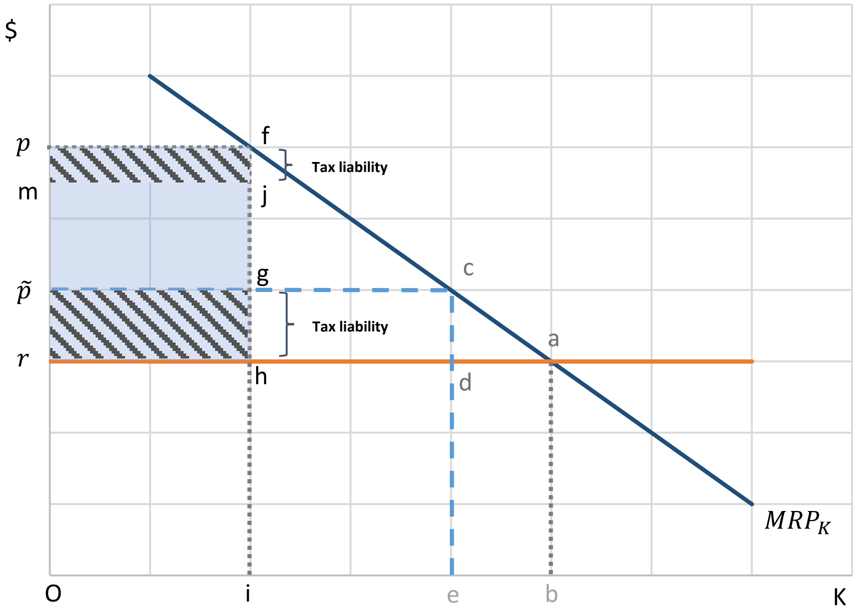
[22] Note that the EMTR can be readily derived from (5) by setting the pre-tax rate of return, p, equal to the cost of capital, which is the pre-tax rate of return on a break-even investment. This EMTR represents the tax-exclusive expression of EMTR.

[23] The qualification “in the presence of taxation” is used here to draw the difference with the economic profit in the absence of taxation given by the area, $pFHr$.

Figure 3. Tax liability on an inframarginal investment



Source: OECD Secretariat adapted from Creedy and Gemmell (2017[34]).

3.2. Interpreting the impact of tax incentives on ETRs

47. R&D tax incentives increase the total value of allowances (A) firms can deduct, reducing the effective cost of the investment to the firm. The extent of this reduction depends on the design and generosity of the R&D tax regime in place. Starting with the marginal investment as defined in Section 3.1.1. the potential impact of R&D tax incentives on the cost of capital can be gauged by reference to the real rate of return r. Three cases can be identified:

- **Case 1: $\tilde{p} > \tilde{p}^{R\&D} > r$. The R&D tax incentive reduces the cost of capital such that it remains above the real rate of return.** In this case, the cost of capital, including the effects of R&D tax incentives $\tilde{p}^{R\&D}$, is lower than the cost of capital without R&D tax incentives $\tilde{p}$. However, despite this support, the firm still needs to realise a higher return to break-even after tax.

  As R&D tax incentives reduce the effective cost of investment to the firm, the amount of R&D investment increases from E to E' in Figure 4 Panel A upon the application of the R&D tax incentive. The tax liability of the firm in the presence of the R&D tax incentive is now given by the shaded region $\tilde{p}^{R\&D}C'D'r$.

- **Case 2: $\tilde{p} > r > \tilde{p}^{R\&D}$. The R&D tax incentive reduces the cost of capital below the real rate of return**. In this case, no tax liability is due; instead, R&D investments are subsidised through the corporate tax system in the form of a negative tax liability, as depicted by the region $rD'C'\tilde{p}^{R\&D}$ in Figure 4 Panel B. Due to this subsidy, the level of investment, E', is larger than in the case without corporate taxes, i.e., beyond the break-even point, B. The tax subsidy therefore renders certain investments profitable that would otherwise not have been viable at the given private rate of return r. These are the investments between the investment level B (break-even point) and E'. The more generous the R&D tax relief provisions, the more likely this case will occur.

  Case 3: $\tilde{p} > \tilde{p}^{R\&D} = r$. **The R&D tax incentive lowers the cost of capital such that it equals the real rate of return**. The generosity of the R&D tax incentive is such that the firm exactly breaks even (zero profit) and taxation thus does not influence the investment choice of the firm. In this case, there is no tax liability arising on a marginal investment and corporate taxation is neutral to the R&D investment in the sense that the firm invests as if no taxation was due, i.e. B in Figure 4.

48. Depending on how generous the R&D tax provisions are and how they interact with the other elements of the tax system, the treatment of R&D investments may be characterised by case 1, 2 or 3. Note that the tax-exclusive EMTR for R&D as defined by equation (5) would take a positive value in case 1, a negative value for case 2 and a value of zero in case 3.

49. The impact of R&D tax incentives on EATRs can be derived based on equations (4) and (5). In particular, equation (5) shows that the EATR, corresponding to the case of an inframarginal investment, can be expressed as the total tax liability as a share of the total pre-tax return to the investment. Focusing on the numerator of the EATR, the total tax liability can be decomposed into the following two terms.

$$TaxLiability^{inframarginal} = \underbrace{(\tilde{p} - r)}_{\boxed{\text{Component 1: Taxation of the marginal investment}}} + \underbrace{\tau(p - \tilde{p})}_{\boxed{\text{Component 2: Taxation of economic profits}}}. \qquad (6)$$

50. The first component in equation (6) represents the taxation on the marginal investment. If the generosity of the R&D tax incentive is such that case 1 applies, this term will be positive; if case 2 applies it will be negative and if case 3 applies it will be zero. The second term in the total tax liability represents taxes accruing on the economic profit associated with the inframarginal project; since this component is always taxed at the statutory rate, it will always be positive.

51. As equation (6) suggests, the EATR can vary substantially when accounting for R&D tax incentives. In cases 1 and 3, the resulting EATR will take a value above zero, in this stylised framework where no other tax provisions apply. However, the sign of the EATR in case 2 will depend on the relative size of the first and second component of the total tax liability as defined in equation (6). The EATR could turn negative when case 2 applies and the second component is comparatively small. A very generous R&D tax incentive may yield a negative tax liability on the marginal investment that is larger in absolute value than the tax paid on the economic profits. In this case, the EATR will be negative, indicating a tax subsidy is granted to inframarginal investments. This may occur when R&D tax incentives are very generous and, especially, when statutory CIT rates—at which economic profits are taxed—are relatively low. On the other hand, the second component in (6) will be larger, the higher the pre-tax rate of return, p, that is considered for the R&D investment, as this will be taxed at the statutory CIT rate.[24]

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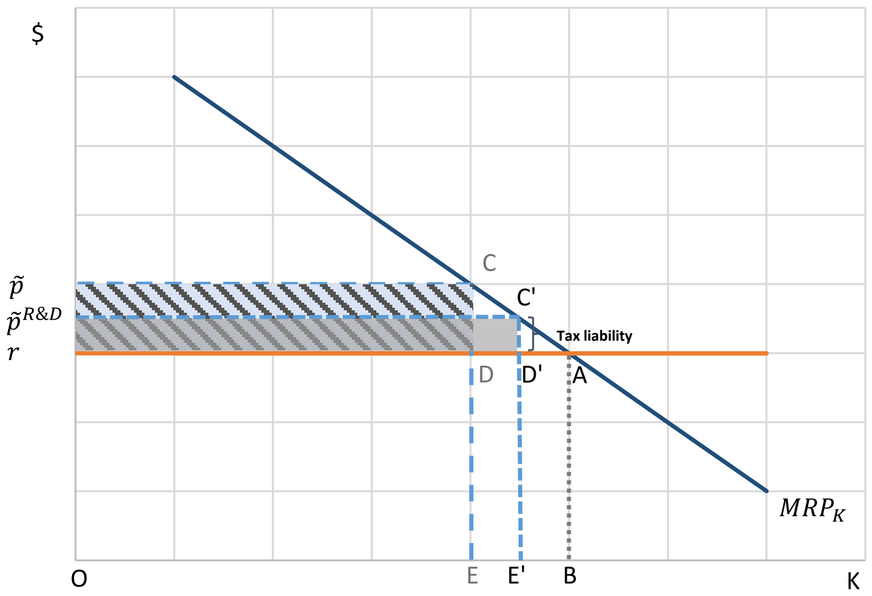
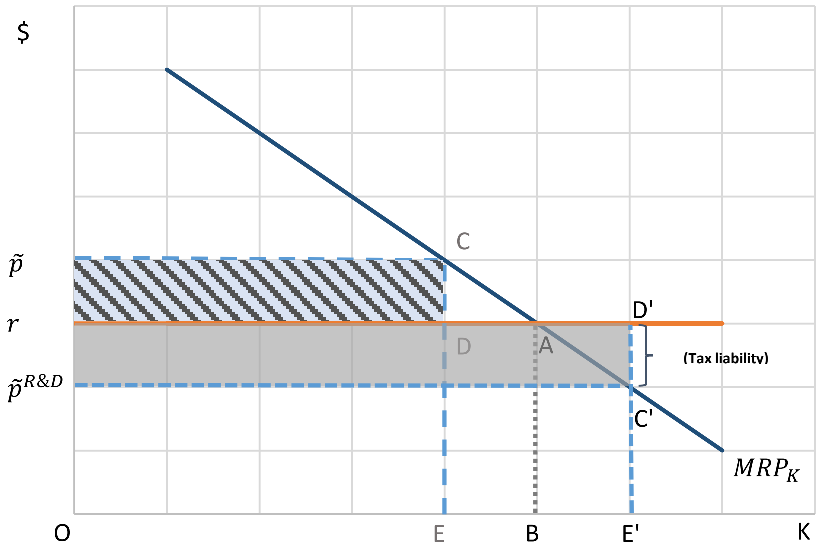
[24] Note that in the absence of personal taxation, the EATR will tend to the statutory CIT rate as the pre-tax return tend to infinity as shown by Devereux and Griffith (2003[5]).

Figure 4. The impact of R&D tax incentives on the marginal investment

Panel A. Case 1: $\tilde{p} > \tilde{p}^{R\&D} > r$



Panel B. Case 2: $\tilde{p} > \tilde{p}^{R\&D} < r$



Source: OECD Secretariat.

4. Modelling ETRs for R&D

52. R&D investments require a mix of current and capital expenditure that may vary across industries and countries. As discussed in Section 2. , the baseline and preferential tax treatment of current and capital R&D expenditure differs across countries. With this in mind, considering that R&D investments may carry differing degrees of both inputs, this section first derives the effect of R&D tax incentives in reducing the

cost of current and capital inputs separately (Section 4.1.). It then presents how input-specific tax allowances can be aggregated to compute the value of total allowances for the R&D investment based on a pre-defined cost composition that can be empirically calibrated (Section 4.2.). Lastly, ETRs including the preferential tax treatment of R&D (Section 4.3.) are derived based on the value of total allowances for the R&D investment for firms which are considered to be sufficiently profitable to fully utilise their tax benefits.

4.1. Modelling input-specific tax allowances

53. Corporate tax systems differ across countries bringing about a variation not only in statutory tax rates but also in corporate tax bases. The latter can be the result of several factors among them different fiscal depreciation rules or the presence of tax incentives, e.g., to support R&D. The effect of expenditure-based corporate tax relief provisions on the effective cost of the investment can be summarised in the parameter A. This parameter captures the net present value of tax allowances, including all tax provisions that lower the effective cost of an R&D investment[25], $1-A$, including the preferential treatment of R&D expenditure whenever it is available. This parameter therefore represents a key component in the calculation of ETRs.[26]

54. This section focuses on modelling the net present value of total allowances, A, in the presence of expenditure-based R&D tax incentives for current and capital expenditure, in alignment with the B-Index estimation (OECD, 2021[3]). To analyse the impact of R&D-specific provisions, Section 4.1.1. models A for the standard case of a non-R&D investment and Section 4.1.2. covers the modelling of expenditure-based R&D tax incentives—the latter solely available to R&D investments. A comparison of the net present value of allowances for an R&D vis-à-vis non-R&D investment is instrumental in measuring the preferential treatment for R&D in a given country with respect to its own baseline.

4.1.1. Standard case: no R&D tax incentives available

55. For capital investments, the depreciation of the asset is generally a deductible expense. Depreciation rules differ across countries and assets (Hanappi, 2018[19]). The value of depreciation over the course of the life of the asset is calculated using the net present value. In some cases, a fraction (or the totality) of the investment is allowed to be immediately expensed. The net present value of the tax allowances, A, can be written as follows.

$$A = \varphi_0 \tau + (1-\varphi_0)\tau Z \qquad (7)$$

In this equation, φ_0 represents the share of the investment immediately expensed, τ the statutory corporate income tax (CIT) rate, and Z the net present value of depreciation.[27]

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[25] The model normalises the size of the investment to one.

[26] Explicitly, the user cost of capital is written as a function of A in equation (3), Section 3.1.1. The EMTR and the EATR are written within the text as a function of the cost of capital in Sections 3.1.1. and 3.1.2. respectively. EMTRs and EATRs can also be explicitly written as a function of A, see Devereux and Griffith (2003[5]).

[27] Z refers to the net present value of the depreciation prior to multiplying it by the CIT rate to turn it into an allowance. This definition of Z is instrumental in modelling the R&D tax provisions. The most common methods of depreciation are declining balance and straight-line. In the first case, the investment is depreciated at a constant rate on its remaining book value; while in the second the investment is depreciated in a constant proportion over its useful life. The net present value in both cases equals $Z_{DB} = \varphi/(\varphi + i)$; $Z_{SL} = \varphi/i\,(1-(1+i)\hat{}(-1/\varphi))$ where φ and ρ represent the capital allowance rate and the discount rate. Depreciation rules are discussed more in-depth in Hanappi (2018[19]).

56. In general, current expenses are immediately deducted (or fully expensed). In this case, $\varphi_0 = 1$, the baseline allowance for current expenses, in net present value terms, would simply equal the statutory CIT rate, i.e., $A = \tau$. Some countries provide the possibility to capitalise a fraction of R&D expenses in particular cases, however, this option is not modelled in this analysis, as it is typically discretional and allowed only under certain conditions.[28]

4.1.2. Enhanced case: R&D tax incentives available

57. Expenditure-based R&D tax incentives are implemented using various design features across countries. These provisions are conditional on the investment being an R&D investment and seek to lower the cost of conducting R&D.

R&D tax credits and R&D tax allowances

58. Most OECD countries offer tax relief through the CIT system in the form of R&D tax allowances or credits. An R&D tax credit reduces the company's tax liability and an R&D tax allowance reduces its taxable income. In the presence of a tax credit, the net present value of allowances are written as follows

$$A = \varphi_0\tau + (1 - \varphi_0)\tau Z + \varphi_0 c + (1 - \varphi_0)c\theta \qquad (8)$$

In this equation c represents the tax credit rate and θ the eligible expenditure that enters the base for the deduction. The first two terms on the right-hand side of equation (8) represent the baseline deduction available to all investment types, and the third and fourth term represents the enhanced treatment given by the R&D tax credit. In the case of a credit on current expenditure which is generally allowed immediate expensing, $\varphi_0 = 1$, equation (8) simplifies to $A = \tau + c$.

59. Enhanced deductions may apply to different types of expenses, e.g., the acquisition cost of an asset or its depreciation value. If the credit applies to the depreciation value of the asset, $\theta = Z$; if it applies to the value of the investment $\theta = 1$. In the case of an R&D tax credit that applies to the depreciation value, the allowances in equation (8) are equal to $A = (\tau + c)Z$, for $\varphi_0 = 0$.

60. If the tax incentive takes the form of an R&D tax allowance, i.e., it is not offsetting the tax liability but the taxable income, then the expression above can be rewritten as follows.

$$A = \varphi_0\tau + (1 - \varphi_0)\tau Z + \varphi_0\tau a + (1 - \varphi_0)\tau a\theta \qquad (9)$$

61. In equation (9), a represents the enhanced tax allowance rate, available on top of the baseline deduction. In countries where there are enhanced depreciation allowances, i.e., cases where the acquisition value of the asset is increased for fiscal purposes, this could be made equivalent to a tax allowance on the value of depreciation.

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[28] According to international accounting rules for intangible assets, an intangible asset can only be recognised if it is likely that it yields economic benefits and the cost can be reliably measured. If these criteria are not met, then the expenditure item is recognised as an expense [IAS 38.21]. The IAS 38 separates expenditures on the research and development phase. Expenditure on research does not meet the criteria outlined above as it is not possible to demonstrate future benefits and therefore they should be expensed and not capitalised. Expenditure on the development phase should be expensed unless the firm can demonstrate the technical and commercial feasibility of the intangible asset for use or sale, i.e. that they are intending and able to complete the asset and use or sell it and are able to demonstrate that it will generate future economic benefits. If all these criteria are met, development costs should be capitalised. Other cases contemplated in IAS 38 may lead to the capitalization of the R&D expense. For instance, a research and development project acquired in a business combination is to be recognized as an asset at cost, including the research component.

Volume-based vs. incremental incentives

62. Tax allowances can apply to the total amount of eligible R&D expenditure (volume-based incentives), or to incremental R&D above a certain predetermined threshold (incremental incentives). Hybrid incentives combine both a volume-based and an incremental component.

63. Volume-based R&D tax credits and R&D tax allowances are modelled as in equation (8) and (9), respectively. In the case of an incremental tax credit, the relief applies only to the qualifying R&D expenditure that exceeds a given base amount. This base amount can be fixed, e.g., R&D tax relief applies to R&D expenditure above EUR 100,000; or can be defined as a firm-specific moving average of qualifying R&D expenditure in the previous k years. When the base amount for the incremental incentive is constant, information on the share of qualifying expenditure is needed for modelling purposes.

64. However, when the base amount represents a moving average of R&D expenditure in previous years, the net present value of an incremental tax credit is calculated factoring in the impact (base effect) that current R&D investment decisions have on the expenditure share that will be eligible in the future.[29] Taking, for example, the case of an incremental tax credit that applies to current R&D expenditure above the firms' three-year average level of R&D expenditure, A, takes the form of equation (10).

$$A = \tau + \left(c - \frac{c}{3}\left(\frac{1}{1+i}\right)^{1} - \frac{c}{3}\left(\frac{1}{1+i}\right)^{2} - \frac{c}{3}\left(\frac{1}{1+i}\right)^{3}\right) \tag{10}$$

In equation (10), i represents the nominal interest rate. The first term in the parenthesis reflects the value of the credit that the firm benefits from in the year of investment. Eligible R&D expenditure for an incremental credit is determined as the average R&D expenditure in the three years preceding the claim. The one unit of R&D invested in year 1 therefore has an impact on the average level of R&D that determines the base amount for the incremental credit in the three subsequent years (i.e., years 2, 3 and 4). This adjustment is captured in the second, third and fourth terms in the parenthesis, where the value of the credit received in year 1 is adjusted by the average level of R&D (accounting for time discounting).

65. Equation (10) can be generalised to the case of an incremental tax credit applicable to qualifying R&D expenditure above the average R&D expenditure in the k preceding years, building on the fact that the expression in brackets can be expressed as a sum of geometric terms, resulting in equation (11).

$$A = \tau + c\left(1 - \frac{1}{ki}(1 - (1+i)^{-k})\right) \tag{11}$$

Analogous to the volume-based tax credit defined in equation (8), the net present value of tax allowances in the presence of an incremental R&D tax credit can be further generalised to yield equation (12).

$$\begin{aligned} A = \varphi_0\tau + (1-\varphi_0)\tau Z + \varphi_0 c\left(1 - \frac{1}{ki}(1-(1+i)^{-k})\right) \\ + (1-\varphi_0)c\theta\left(1 - \frac{1}{ki}(1-(1+i)^{-k})\right). \end{aligned} \tag{12}$$

66. As capital expenditure is typically depreciated, $\varphi_0 = 0$; in this case, setting $\theta = 1$ corresponds to an incremental tax credit that applies to the acquisition cost of the asset, while setting $\theta = Z$ corresponds to an incremental tax credit that applies to the depreciation of the asset.

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[29] This way of modelling incremental R&D tax incentives is standard in the literature, e.g. (Hall and Van Reenen, 2000[30]; Bloom, Griffith and Van Reenen, 2002[35]).

67. The formula for an incremental R&D tax allowance can be derived analogously by replacing the tax credit rate c in (12) with the allowance rate a, multiplied with the CIT rate τ.

Payroll/Social Security Contribution (SSC) incentives

68. R&D tax incentives can also reduce payroll or SSC liabilities, which could ultimately lead to a reduction of the labour cost incurred by the employer.[30] However, a reduction in the labour costs also leads to lower deductible expenses, thereby indirectly increasing the taxable income of the firm. As a consequence, R&D tax incentives based on payroll or SSC are effectively taxable. In the presence of payroll credits or SSC exemptions, the net present value of tax allowances can be expressed as follows.

$$A = \tau + c^{payroll}(1 - \tau) \tag{13}$$

In this equation, $c^{payroll}$ is the rate of relief applicable to payroll taxes or to employer SSCs (to be multiplied by the exemption rate in the case of partial exemptions). Note that (13) only refers to labour costs unless other types of expenditures are covered by this incentive.[31] The first term in (13) captures the deductibility of labour costs, i.e., assuming $\varphi_0 = 1$, and the last term in equation (13) reflects, firstly, the reduction of wage costs due to the payroll credits or SSC exemptions and, secondly, the reduction in the baseline deduction of labour cost (and the consequent increase in taxable income).

Accelerated or enhanced depreciation for R&D

69. In some countries, investments in capital assets used in the context of an R&D investment are eligible for accelerated depreciation, allowing firms to depreciate capital inputs used for R&D purposes faster than in the context of an equivalent capital investment used for non-R&D purposes. The term 'acceleration' in this context refers to an accelerated depreciation treatment with respect to an equivalent investment used in a non-R&D context.[32] Under accelerated depreciation, as opposed to enhanced depreciation, the firm cannot write-off more than 100% of the acquisition cost of the asset. When accelerated depreciation provisions for R&D are in place, the net present value of the depreciation of the asset under accelerated depreciation rules would be larger than under baseline depreciation rules. In short, the net present value of depreciation will take the same form as in (7) but replacing the net present value of depreciation without the preferential treatment to R&D, Z, by Z^{acc} where $Z^{acc} > Z$. In consequence, when accelerated depreciation is in place, the value of tax allowances, i.e., A, will be higher, ceteris paribus, reaching τ in the most favourable case of an immediate write-off.

70. Enhanced depreciation allowances imply that the acquisition value of the asset is increased for fiscal purposes, e.g., for an investment that was acquired for EUR 10,000, the firm can write-off a total of

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[30] Empirical evidence investigating the impact of expenditure-based R&D tax incentives in business R&D typically find a positive effect of R&D tax incentives in R&D expenditure. Some of this positive effect may be driven by higher R&D wages if supply is inelastic. The price vs. quantity effect has been researched in the literature using different methodologies, datasets and level of data aggregation, but the empirical evidence yields mixed results. For instance, Wolff and Reinthaler (2008[50]) for a panel study and Lokshin and Mohnen (2013[49]) for the Netherlands find evidence of a price effect while Thomson and Jensen (2013[48]) for a panel study and Guceri (2018[31]) for the United Kingdom do not find support for a price effect. Given this, tax incentives that seek to lower the wage cost to the employer are modelled under the simplifying assumption that the reduction in wage cost from the incentive is not passed on to the employees as higher wages.

[31] The payroll withholding tax credit in the Netherlands (WBSO), for instance, covers non-labour related costs following the merger of its previous WBSO scheme and R&D tax allowance in 2016.

[32] R&D investment; see footnote 12.

EUR 13,000 in capital allowances over the full project lifetime. In this case, the net present value of depreciation will be also higher than baseline, where $Z^{enh} > Z$. Enhanced depreciation allowances can be modelled, as described in detail below, as an equivalent tax allowance on depreciation.

Taxability

71. R&D tax benefits are taxable in some countries. Tax benefits may represent taxable income or be incompatible with baseline tax deductions. For example, the R&D tax credit for large enterprises (RDEC) in the UK and the Scientific Research and Experimental Development (SR&ED) in Canada treat the tax credit as part of taxable income, which implies a corresponding increase in pre-tax profits. In other countries, the baseline tax deduction is reduced by the amount of the credit (United States), or completely foregone in order to benefit from R&D tax relief (Australia). In general, as noted above, payroll or SSC incentives (as, e.g., in Belgium, Netherlands) are effectively taxable as well.

Multiple R&D tax relief provisions

72. In order to calculate the net present value of tax allowances for a given R&D investment and capture the actual effect of tax incentive provisions any possible interaction effects between individual R&D tax incentives need to be accounted for in the modelling. For example, the effects of a volume-based R&D tax allowance that applies to the depreciation of an asset can be combined with accelerated depreciation, by setting $\varphi_0 = 0$ and $\theta = Z^{acc}$.

$$A = \tau Z^{acc} + \tau a Z^{acc}. \tag{14}$$

4.2. *Estimating the value of total tax allowances for the R&D investment*

73. Section 4.1. discussed how different R&D tax incentives can be incorporated in the calculation of the net present value of total tax allowances for current and capital R&D expenditures, A. This approach reflects the variation in the tax treatment of different types of R&D expenditures across countries. However, current and capital expenditure are only inputs to the creation of the R&D asset that will generate a revenue stream over time. Following Lester and Warda (2014[22]), a production function with fixed proportions is assumed, implying that the total tax allowances associated with the R&D investment are calculated by aggregating the input-specific tax allowances using their relative share in the R&D investment as weights.[33][34] This approach yields the net present value of total tax allowances that would accrue to a given R&D investment, i.e. $A^{R\&D}$.

74. The net present value of the total tax allowances for an R&D investment is thus defined as a weighted average of the underlying input-specific tax allowances.

$$A^{R\&D} = w^C * A^C + w^{TAN} A^{TAN} + w^{NRS} A^{NRS} \tag{15}$$

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[33] As will be seen in Section 4.3. this approach treats current expenditure as an investment, i.e. its full value is not realised immediately but is capitalised at the same rate as the R&D asset it is used to create.

[34] Bloom et al. (2002[35]) use a different approach as they consider the impact of R&D tax incentives in the cost of capital of different types of current and capital investments used for R&D. These are then aggregated using their share in the average expenditure-mix. This approach maintains the link between the economic and fiscal depreciation for each asset but does not account for the economic depreciation of the R&D asset itself. This approach is also followed in Bösenberg and Egger (2017[24]).

In this equation, w represents the input shares and the superscript $R\&D$ refers to the R&D investment, C to current expenditure, TAN to investments in tangible assets and NRS to investments in non-residential structures.

75. Equation (15) provides a flexible structure to incorporate different types of expenditure incurred as part of the R&D investment that can also accommodate more disaggregated cost breakdowns. For instance, current expenditure is composed of labour and other current expenditure. This distinction and the use of separate weights for labour and other current expenditure allows the modelling of SSC or payroll incentives that provide a reduction to the labour-specific share of current expenditure. The formula in (15) is adjusted to reflect that the preferential tax treatment only applies to this fraction of current expenditure. Let A^{L} be the NPV of allowances applying to labour costs and A^{OT} that applying to other current expenditure, the revised weighted total allowances rates for R&D would be given by:

$$A^{R\&D} = w^{C} * \left(\left(w^{L} / w^{C} \right) A^{L} + \left(w^{OC} \,/\, w^{C} \, \right) A^{OC} \right) + w^{TAN} A^{TAN} + w^{NRS} A^{NRS} \qquad (15a)$$

76. Using the same approach, a comparable non R&D related investment that does not benefit from R&D tax support can be constructed to provide a relevant counterfactual. That is to say, the net present value of total tax allowances for an otherwise comparable non-R&D investment can be calculated using the same weighted average value of input-specific tax allowances under the assumption that no enhanced provisions are available. The only difference between the R&D investment and the comparable non-R&D investment is the enhanced treatment that the tax system grants to R&D investments - all other features of the tax system remaining constant. The comparable non-R&D investment project therefore presents a country-specific benchmark for assessing the total value of R&D tax relief within a framework that is comparable across countries.

4.3. Estimating effective tax rates for the R&D investment

77. Once the value of total tax allowances for the R&D investment has been estimated, the estimated value of total tax allowances for an R&D investment, $A^{R\&D}$—equation (15) — is substituted into the expressions of the cost of capital and the EATR—equations (3) and (5) respectively— to yield $\tilde{p}^{R\&D}$ and $EATR^{R\&D}$. Likewise, the ETRs for a comparable non-R&D investment, labelled non-R&D $NR\&D$, can be estimated by the same procedure using $A^{NR\&D}$, instead of $A^{R\&D}$. The cost of capital is presented instead of $EMTR^{R\&D}$ as the primary indicator to analyse decisions at the intensive margin, referring to the marginal investment. EMTRs are simply a transformation of the latter (Section 3.1.1.). Given the large component of current expenditures in R&D investments, EMTRs are likely to be large and negative, challenging the interpretability of results.

5. Empirical calibration

5.1. R&D tax incentives parameters

5.1.1. Defining an R&D investment

78. Modelling the effective tax rate applicable to an R&D investment requires defining the expenditure mix used to produce the R&D asset (Section 4.2.). For the purpose of this analysis, R&D statistics on intramural R&D expenditure by type of cost (excluding extramural R&D, i.e. payments for subcontracted R&D) are used to calibrate the composition of a typical R&D investment across OECD and partner economies.

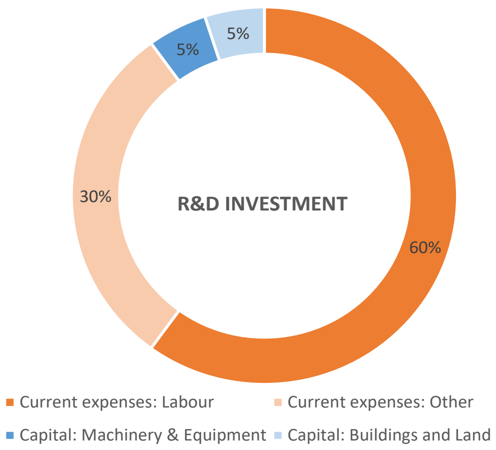
79. The mix of current and capital costs in total intramural R&D expenditure varies across countries, but across the board R&D investments are characterised by a heavy weight towards current vs capital

expenditure (see Annex B for further detail). On average, current expenditure represents around 90% of total intramural R&D expenditure in OECD countries; with labour costs representing about two-thirds of current costs. Based on these aggregated cross-country averages, the R&D investment is calibrated for modelling purposes (Figure 5) as a mix of:

- 90% current expenditure (w^{C} in equation (15a)), with 60% being labour costs (w^{L} in equation (15a)), and the other 30% other current costs, e.g. materials, overheads (w^{OC} in equation (15a))
- 10% capital expenditure, with an even split assumed for investment in tangible assets and investment in non-residential structures due to the lack of more disaggregate data on R&D capital expenditure by type of capital asset (w^{TAN} and w^{NRS} in equation (15a)).

Figure 5. Composition of a stylised R&D investment for modelling purposes

Based on the cross-country average composition of R&D expenditure



Source: OECD Secretariat, calculations based on Research and Development Statistics database http://oe.cd/rds, September 2020.

80. This cost composition of the typical R&D investment is standard in the R&D literature (Warda, 2001[17]; Bloom, Griffith and Van Reenen, 2002[35]; OECD, 2020[36]). Evers et al. (2013[21]; 2015[23]) in their main specification and subsequently Pfeiffer and Spengel (2017[37]) consider the R&D investment to be 100% current expenditure as a simplifying assumption, since it is the largest component in the project. While it would generally be possible to calibrate the model to map country and industry-specific patterns of the R&D expenditure mix[35], the composition of the R&D investment is held constant for the purposes of this analysis. Using a common R&D investment composition for all countries ensures that any cross-country variation obtained from the modelling of effective tax rates for R&D is fully attributable to the tax system and R&D tax relief provisions more specifically.

81. It is important to note that these figures are aggregates of the total economy and mask the heterogeneity in the expenditure mix that might exist between firms operating in different sectors and countries as well as within firm heterogeneity in the types of projects undertaken. In Annex D, using R&D statitsics, alternative calibrations of the composition of the R&D expenditure-mix are used to reflect the impact of R&D tax incentives on the cost of R&D through the different treatment of current vs. capital R&D expenditures.

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[35] See for instance Thomson (2017[46]).

5.1.2. Design features

82. Data on the design of R&D tax incentives are collected as part of the annual OECD R&D tax incentive survey. This data collection is conducted by STI in collaboration with members of the OECD R&D tax incentive network, formed by national experts from science and research ministries, finance ministries, and tax revenue agencies. This data collection brings together experts from the Working Party of National Experts on Science, Technology and Innovation and from the Working Party No.2 on Tax Policy and Statistics. To this date, the underlying survey has compiled information on the design of R&D tax incentives (2000-20) and their (ex-post) tax expenditures (2000-18), overall covering 48 OECD and partner economies.[36] The calculations of ETRs for R&D in this paper build upon the same design features and the same modelling of R&D tax incentives as the B-Index (OECD, 2021[3]). Annex C provides a list of the expenditure-based R&D tax incentive provisions modelled in Section 6.

5.2. Economic depreciation rate of the R&D asset

83. Economic depreciation rates are hard to measure for intangibles. In line with previous literature, this study considers the economic depreciation rate for R&D assets to be 15% (Hall, 2007[38]; Evers, Miller and Spengel, 2013[21]; Lester and Warda, 2014[22]). However, it is recognised that R&D depreciation rates might differ extensively across sectors and over time (Li and Hall, 2020[39]). It is left to future work to explore differences in the economic depreciation rates of alternative R&D projects.

84. As discussed in Section 4.2. , current and capital inputs contribute to the production of the R&D asset. However, the relevant economic depreciation rate is that of the R&D asset, and not that of the components that are used to create it. Implicitly, the economic depreciation rate of current and capital inputs is assumed to be the same as the one of the intangible R&D asset that is produced based on these inputs.

5.3. General tax parameters

CIT rates and baseline tax depreciation rules and rates are obtained from the OECD Corporate Effective Tax Rates data collection undertaken via Working Party No.2 on Tax Policy Analysis and Tax Statistics (WP2). Baseline estimates in this paper are aligned with the depreciation rules and rates used to compute corporate effective tax rates published as part of the Corporate Tax Statistics (OECD, 2020[16]). This includes the presence of notional interest deductions as covered in the explanatory annex (OECD, 2020[40]) When countries report that accelerated depreciation is available for capital inputs used for R&D purposes, the baseline depreciation treatment captured as part of Corporate Tax Statistics is replaced with the respective accelerated depreciation scheme.

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[36] Thirty-seven OECD countries and eleven partner economies (Argentina, Brazil, Bulgaria, China, Croatia, Cyprus, Malta, Romania, the Russian Federation, South Africa and Thailand).

Note by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the “Cyprus issue”.

Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

5.4. Economic parameters

85. A key parameter in the model for the estimation of the effect of taxation on an inframarginal investment is the pre-tax rate of return of the project, i.e., p in equation (5). In the case of R&D, the literature distinguishes between the private returns to the firm performing R&D and the social returns to R&D which additionally comprise the returns to R&D accruing to any recipients outside the firm in the form of knowledge spillovers. As this analysis focusses on the measurement of the incentives of the firm in performing R&D, the parameter p captures the private return on the R&D asset. As Hall, Mairesse and Mohnen (2009[41]) point out, this parameter is not a 'scientific constant' but an outcome of several factors, among them firm and competitor strategies and the wider economic environment. In general, the returns to R&D will vary across sectors, countries and likely over time.

86. The review of estimates performed by Hall et al. (2009[41]) confirms the great variability of estimates, e.g. across units of observations and methodologies used, reporting estimates up to 75%. However, the authors also mention that the most likely range for the private return to R&D is around 20-30%. These empirical estimates are higher than those typically used in the literature on forward-looking effective tax rates on inframarginal investments, which often assumes a rate of 20% (ZEW, 2015[42]; OECD, 2020[40]).[37] The risks associated with R&D investments and the asymmetric information between the shareholders and the firm conducting the R&D may explain, among other factors, the higher pre-tax rates of return to R&D compared to non-R&D related investments. In line with the empirical estimates discussed here, the pre-tax return of the R&D investment is calibrated to the average rate of p=30% for the purpose of this analysis. As a robustness check, a sensitivity analysis is performed in Annex E where results are presented for a private return of 20%, 30%, 50% and 75%.

87. There are two key macroeconomic parameters in this model: the real interest rate and the inflation rate. Both of them are linked to the nominal rate of interest by means of the Fisher equation.[38] The real interest rate is set to 3% and the inflation rate to 1% in line with the 'low' scenario considered in Hanappi (2018[19]) and in Corporate Tax Statistics (OECD, 2020[16]; OECD, 2020[40]). Table 2 contains the values of the key modelling parameters used.

Table 2. Key model parameters

Parameter		Value
Pre-tax rate of return	p	30%
Real interest rate	r	3%
Inflation	π	1%
Economic depreciation rate	δ	15%

Note: This table summarises the parameters used for the main calibration of results in Section 6.
Source: OECD Secretariat.

5.5. Other modelling assumptions

88. Models of ETRs become more complex as more features of the tax system are accounted for. In line with Corporate Tax Statistics, the model used here abstracts from the inclusion of personal income taxes and other related taxes such as real estate taxation. The investment is considered to be a domestic

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[37] Devereux and Griffith (2003[5]) in the empirical application at the end of their seminal paper provide results for a range of private rates of return to R&D. Modica and Neubig (2016[47]) also assume a rate of 30% to model the taxation of knowledge-based capital focusing on non-R&D investments.

[38] See footnote 16.

investment, i.e. cross-border investments are not considered at this point although the effect of these provisions could be investigated as part of future work.[39] For the purpose of this analysis, the investment is assumed to be financed by retained earnings for simplicity. Considering other types of financing structures is possible and could be explored as part of future work. If debt financing or a mix of equity-debt is assumed it would affect the ranking of countries in the cross-country comparison. However, different assumptions on the type of financing would not affect the estimates of the preferential treatment to R&D measured within countries, defined as a departure from the tax treatment to a comparable non-R&D investment (as long as they are applied symmetrically to both investment projects).[40] The stylised model used for this estimation seeks to focus on the modelling of R&D tax incentives in isolation from other components of ETRs.

89. ETRs for R&D investments are modelled for large firms, which are assumed to be profitable enough to utilise their tax benefits from R&D. As discussed in Section 2. , certain countries provide preferential tax treatment to SMEs and loss-making firms on the grounds that market failure is particularly acute for this firm type. While policy relevant, the analysis of the impact of R&D tax incentives on the ETRs for these firm types is currently not modelled but could be investigated as part of future work. Design features such as carry-overs or refundability are therefore not accounted for. However, interested users may consult estimates of the B-Index that are available for four scenarios of firm size (i.e., those benefitting from SME-related provisions and others) and profitability (i.e., distinguishing between firms with and without sufficient profits to use the tax benefits), covering 48 countries from the year 2000 (OECD, 2021[3]). ETRs are calculated for R&D tax incentives available at the national level (subnational incentives, available in a few OECD countries,[41] are not considered), see Annex C.

90. Certain design features that limit tax benefits for R&D such as the presence of ceilings and thresholds are assumed not to be binding due to a lack of data reflecting the share of R&D expenditure or performers bound by these limitations. Implications for the results follow in Section 6.

6. Results

91. The results presented in this section allow for an assessment of the extent of preferential treatment to R&D both within and across countries.

- *Within* countries, the preferential tax treatment to R&D granted through R&D tax incentives is measured as a deviation from the tax treatment that a comparable non-R&D investment would receive in the same jurisdiction. This approach provides policy-makers with a tool to evaluate the preferential tax treatment provided to R&D in isolation from the baseline tax provisions available to

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[39] The extension to cross-border investments would need to account for the nature of the cross-border investment and the linkages between the parties involved in the transaction as this would have implications for the way it is taxed (Grubert, 2003[44]; Devereux and Griffith, 2003[5]; Pfeiffer and Spengel, 2017[37]).

[40] The impact of expenditure-based R&D tax incentives is captured in the value of total allowances, i.e., A. Model changes to incorporate alternative ways of financing are independent of this parameter, see Hanappi (2018[19]) for extended formulae. Therefore, taking the difference between the ETRs for an R&D and a non-R&D investment using different sources of finance would yield the same estimated difference between the two investments, which is used in this paper as a measure of the preferential treatment to R&D.

[41] Subnational R&D tax incentives are available in certain countries, e.g. Canada, Hungary, Japan, Spain and the United States. Subnational R&D tax incentives account for nearly 30% of total tax support in Canada in 2017, playing a comparatively smaller role in Hungary (16% of total tax support) and Japan (less than 1% of total tax support) (OECD, 2021[3]). Modelling the impact of subnational incentives in the B-Index and ETR indicators is possible while not explored in this paper.

all types of investments. It is important to distinguish the effect of R&D tax provisions from the baseline tax treatment, particularly when the latter are generous.[42]

- *Across* countries, the generosity of the tax treatment provided to R&D investments can be gauged by comparing the ranking of countries using measures of the cost of capital and EATR for R&D, for the marginal and inframarginal case.

92. The estimates refer to the year 2019 and cover 48 countries including OECD and EU countries, as well as six partner economies, Argentina, Brazil, China, the Russian Federation, South Africa and Thailand. In 2019, only Argentina[43], Bulgaria, Cyprus[44], Estonia, Finland, Germany, Latvia, Luxembourg and Switzerland did not offer expenditure-based R&D tax incentives.[45] Estimates are based on the parameters outlined in Section 5. Differences in the empirical calibration of the indicators may yield differences in the resulting estimates. Annex D and Annex E provide sensitivity analysis around two key parameters: (i) the composition of the R&D investment and (ii) alternative private rates of return.

93. As discussed in Section 2. , certain countries have ceilings or thresholds in place in order to limit the amount of eligible R&D or the value of the tax benefits firms can access. In this exercise, due to data limitations, ceilings and thresholds are assumed not to be binding, i.e. the firms can fully utilise their tax benefits (see Section 5.5.). Not accounting for ceilings where they effectively limit firms' tax benefits, entails that ETRs in this section should be interpreted as the most generous treatment that firms would be able to access in a given country. However, it is important to note that the impact of this assumption on the results depends on how far the ceiling actually curtails firms' tax benefits. In certain cases, the ceiling might be high enough that it does not meaningfully affect firms' tax benefits and the ETRs presented in Section 6.3. would not be significantly affected by this assumption.[46]

94. The section is structured in three parts:

- The first part (Section 6.1.) presents cross-country input-specific tax allowances, A, that feed into the combined value of total tax allowances for the R&D investment. The size of A provides a first

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[42] For instance, consider that a given country introduces a new scheme that allows firms to write-off investments in all tangible assets independent of their use in one-third of their usual asset life. Both R&D and non-R&D investments using tangible assets would receive exactly the same treatment, and the extent of preferential treatment to R&D using this measure would then be zero.

[43] Argentina has an R&D tax incentive in place but there was no call for it in 2019, therefore it is listed in this paper as not offering a tax incentive in 2019.

[44] Note by Turkey:

The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union:

The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[45] Germany introduced expenditure-based R&D tax incentives in 2020. Switzerland introduced an optional R&D tax deduction at cantonal (subnational) level in 2020, however no expenditure-based R&D tax incentives are available at the central government level.

[46] For a review of countries with ceilings and thresholds and the impact of ceilings and thresholds in a selected set of countries see (OECD, 2020[36]).

indication of the magnitude of R&D tax relief for each R&D input across different countries. Both the eligibility and generosity of R&D tax provisions for each R&D input affect the total value of tax allowances for the R&D investment.

- The second part (Section 6.2.) studies the cross-country variation in the value of total tax allowances for the R&D investment, aggregating the value of tax allowances for each R&D input according to its relative weight in the R&D investment.
- The third part (Section 6.3.) presents the result on the cost of capital, as well as effective average tax rates for the R&D investment across all covered countries, building upon the value of total tax allowances for the R&D investment derived in Section 6.2.

6.1. Input-specific tax allowances

6.1.1. The value of tax allowances for R&D inputs

95. Figure 6 presents the value of tax allowances for current expenditures (A^C in Section 4.2.). The value of tax allowances is presented as a percentage of the initial investment, i.e. an investment of one monetary unit. In Figure 6, the diamonds represent the value of A^C when current expenditure is incurred in the context of an R&D investment, incorporating the value of enhanced tax provisions for current expenditures whenever those qualify for R&D tax support. The circles reflect the standard tax treatment of current expenditure, i.e., the tax allowances for current expenditure available to the firm for non-R&D related investments. Countries are ranked by their statutory CIT rate, as indicated by the clear bars in Figure 6.

96. The value of tax allowances equals the statutory CIT rate when immediate deduction is allowed (i.e., the asset is fully expensed) and no other enhanced R&D tax provisions are in place.[47] Since current expenditure is, in general, immediately deductible for a non-R&D investment, the value of tax allowances typically equals the statutory CIT rate, i.e. the circles overlay the top of the bars in Figure 6.[48]

97. R&D tax incentives lower the cost of R&D. When in place, they increase the allowances firms can additionally deduct, A, and effectively lower the after tax cost of the investment, $1 - A$. When R&D tax incentives apply to current expenditure, the value of tax allowances for current expenditure is higher than in the standard non-R&D case, as indicated by diamonds placed above the circles in Figure 6. This is the case for a majority of all countries. See for example, Ireland, Portugal and Spain.

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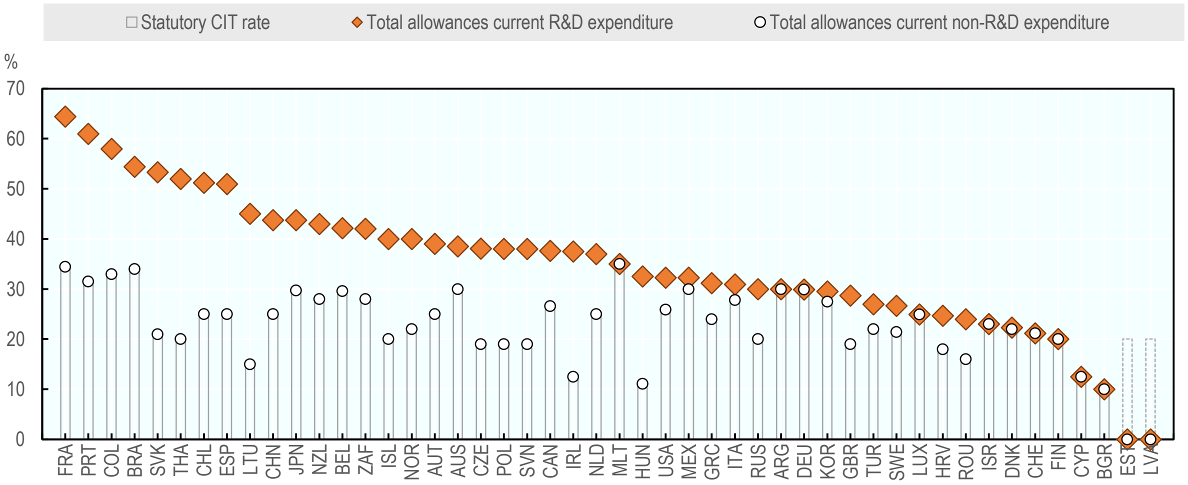
[47] This follows from equation (2), when $\varphi_0 = 1$ indicating full-expensing, $A = \tau$.

[48] In some countries firms have the possibility to capitalise a fraction of R&D expenses in particular cases, however this option is not modelled in this paper, as it is typically discretional and allowed under certain criterion. Expensing is also the recommended tax treatment under international accounting rules, cf. footnote 28.

Figure 6. Tax allowances for current expenditures on R&D and non-R&D investments



Note: The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits.
Source: OECD Secretariat calculations.

98. In Figure 6, the diamond and the circle will overlap when no preferential tax treatment is granted to R&D investments. This is the case for countries offering no expenditure-based R&D tax incentives, i.e., Argentina, Bulgaria, Cyprus, Estonia, Finland, Germany, Latvia, Luxembourg and Switzerland[49]; or when existing R&D tax incentive provisions do not apply to current R&D expenditure, as is the case for Israel.

99. The value of baseline and enhanced tax allowances is generally higher in countries with higher statutory CIT rates. However, the ranking changes when R&D tax provisions are accounted for due to the differing generosity of these provisions across countries. Comparing the diamonds and circles in Figure 6, the largest tax allowances for non-R&D investments are offered in Malta, France and Brazil, while the largest tax allowances for R&D investments are offered in France, Portugal and Colombia.

100. Figure 7 presents the value of tax allowances for capital inputs to the R&D investment, i.e., tangible assets and non-residential structures in Panels A and B respectively (A^{TAN} and A^{NRS} in Section 4.2.). In the case of capital expenditure incurred in the context of non-R&D related projects, most countries allow firms to deduct the depreciation value of the asset. This yields a capital allowance in the non-R&D case that is lower than the statutory tax rate[50] (as indicated by the circles being below the top of the bars in Figure 7), unless immediate deduction (i.e., full expensing) is allowed. The position of the diamond indicates the value of tax allowances for R&D related capital inputs. The distance between the diamond and the circle highlights the extent of preferential treatment to R&D capital expenditure in a given country.

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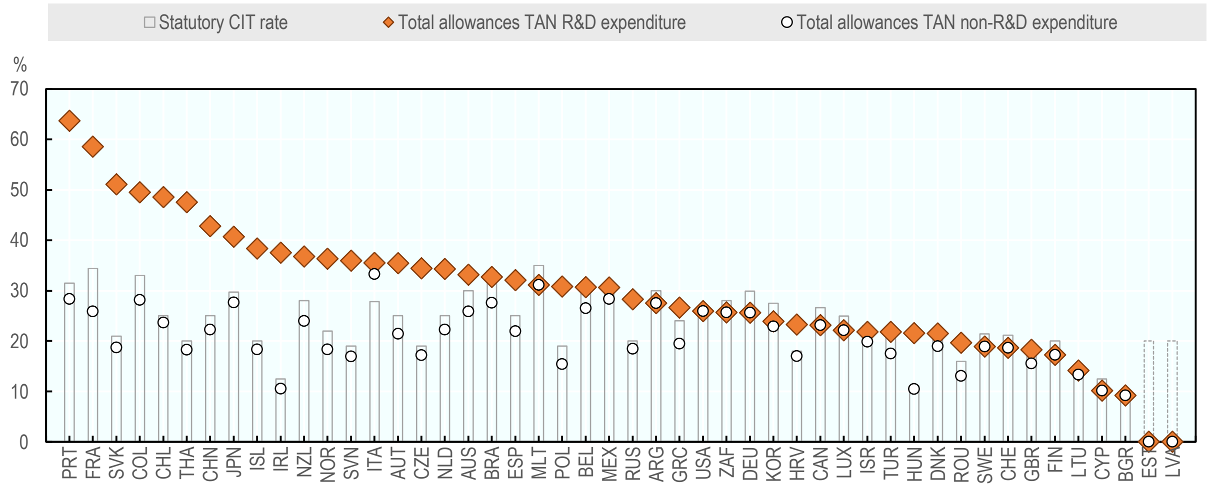
[49] Malta repealed the enhanced R&D tax allowance, available at a rate of 50%, with retroactive effect from 2019. In 2019, Malta offers additional R&D tax credits. However, due to their very limited uptake, they are not accounted for in the modelling.

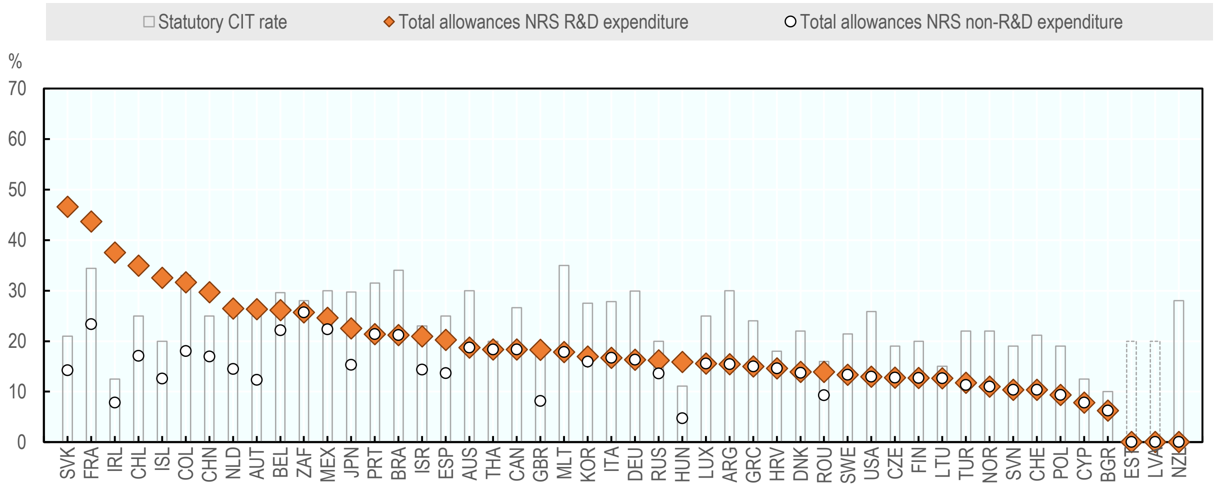
[50] This statement follows from the fact that under full expensing the value of capital allowances equal the statutory CIT rate. Allowing the deductibility of the depreciation of the asset over time implies that the net present value of depreciation allowances will be lower than the cost of the one unit invested, $Z < 1$, due to the impact of discounting. This implies that $A < \tau$.

Figure 7. Tax allowances for capital expenditures on R&D and non-R&D investments

Panel A: Capital expenditure – Tangible assets



Panel B: Capital expenditure – Non-residential structures



Note: The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits.
Source: OECD Secretariat calculations.

101. In Figure 7, the value of tax allowances for capital expenditures incurred as part of an R&D investment (i.e., the diamonds) will overlap with the corresponding value for non-R&D investment (i.e., the circles) for those countries where capital expenditures do not qualify for R&D tax support. This is the case, e.g., in Sweden for all types of capital expenditure and in Portugal for non-residential structures. Furthermore, as for current expenditures, the value of tax allowances on capital expenditures for an R&D and a non-R&D related investment will coincide when no specific R&D tax provisions are in place, as, e.g., in Germany, Luxembourg and Finland.[51] Cross-country differences in the treatment of R&D expenditure

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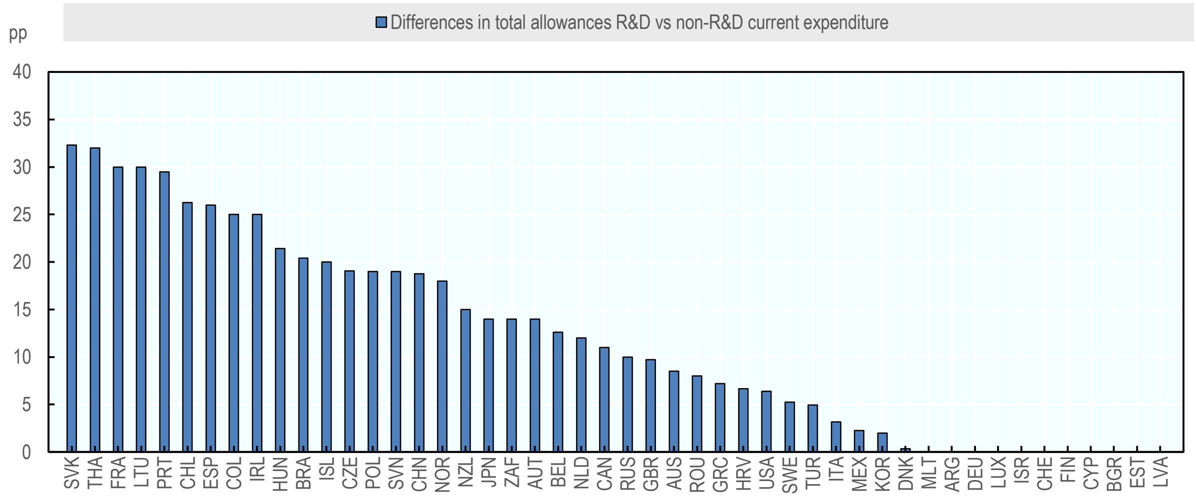
[51] When no R&D tax incentives are in place, the value of capital allowances matches that in Corporate Tax Statistics, with the exception of tangible assets in Italy. For the purpose of this analysis, the capital allowance for tangible assets is a weighted average that reflect the tax treatment of regular tangible assets and the preferential tax treatment to highly digitalised tangible assets, using their respective shares in investment as reported in the National Accounts as weight.

can be observed based on the value of input-specific tax allowances. As most countries do not provide tax support for non-residential structures, the diamond and the circle typically overlap.

6.1.2. Isolating the impact of R&D tax incentives on input-specific tax allowances

102. The distance between the diamond and the circle in Figure 6, the R&D vs. non-R&D case, provides a *within*-country comparison of the extent of preferential tax treatment provided to R&D, in isolation from the standard tax treatment available to *all* types of investment. Figure 8 provides a direct comparison of the treatment of current expenditures for an R&D and non-R&D investment. The higher the bar, the more generous the tax incentive provisions for R&D investments in a particular country compared to an equivalent non-R&D investment. The most generous treatment for current R&D expenditure using this within country comparison is offered in the Slovak Republic, followed by Thailand, France, Lithuania and Portugal.

Figure 8. Difference in tax allowances for current expenditure on R&D and non-R&D investments



Note: The effect of R&D tax incentives is measured as difference in the value of tax allowances of R&D and non-R&D investments reported in Figure 6.
Source: OECD Secretariat calculations.

103. Figure 9 provides the analogous figure for capital expenditures. Comparing the three graphs in Figure 8 and Figure 9 (Panels A and B) gives an indication of differences in the tax treatment of R&D inputs across countries, both in terms of eligibility and generosity. For example, the R&D tax credit in Portugal grants preferential treatment to current R&D expenditure and R&D tangible assets but not to non-residential structures used for R&D (i.e., there is no bar for Portugal in Panel B of Figure 9). In Lithuania, the R&D tax allowance only applies to current expenditure. Ireland's R&D tax credit offers relief for all three inputs. Argentina, Bulgaria, Cyprus, Estonia, Finland, Germany, Latvia, Luxembourg and Switzerland do not offer R&D tax support in 2019—no bar is displayed for any of the three inputs. Out of the 48 countries considered, 38 countries offer R&D tax incentives in 2019, 21 of which offer relief for all types of current and capital R&D expenditure, 13 countries offer relief for current expenditure and tangible assets and 4 countries provide relief exclusively for current expenditure.[52]

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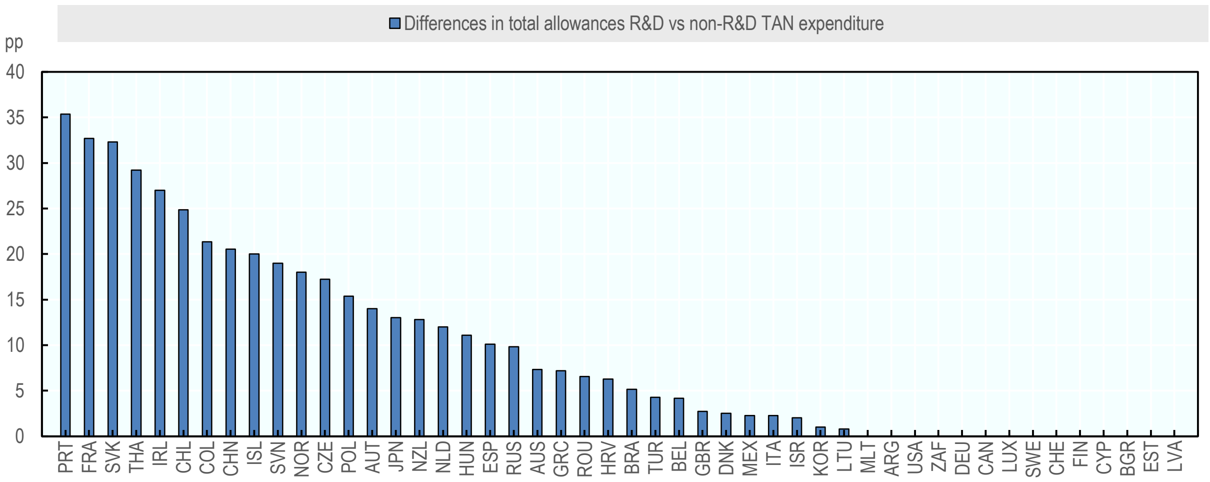
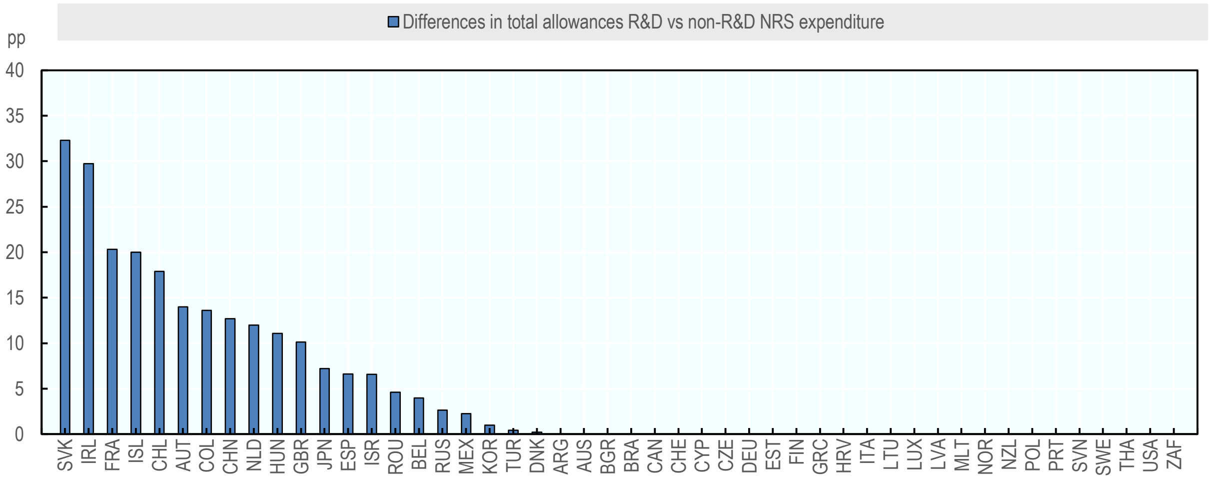
[52] Statistics refer to R&D tax incentives modelled (see Annex C and footnote 50 for the case of Malta). The 21 countries are Austria, Belgium, Chile, China, Colombia, Denmark, France, United Kingdom, Hungary, Ireland, Iceland, Japan, Korea, Mexico, Netherlands, Romania, the Russian Federation, Slovak Republic, Spain and Turkey. The 13 countries

Figure 9. Differences in tax allowances for capital expenditures in R&D and non-R&D investments

Panel A: Capital expenditure – Tangible assets



Panel B: Capital expenditure – Non-residential structures



Note: The effect of R&D tax incentives is measured as difference in the value of total tax allowances of R&D and non-R&D investments (Figure 7).
Source: OECD Secretariat calculations.

6.1.3. Design features of R&D tax incentives

104. Enhanced tax allowances for R&D inputs tend to be higher in countries where the R&D tax incentive has a volume-based component. This is the case for Portugal and Spain, where a hybrid incentive is offered,[53] and France and Lithuania, where volume-based R&D tax incentives are offered. However, the extent of the generosity depends strongly on the headline tax credit or allowance rate. The United Kingdom, for instance, offers a volume-based Research and Development Expenditure Credit (RDEC) for large enterprises at a rate of 12% that implies a small increase in the value of tax allowances. Smaller tax

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are Australia, Brazil, Croatia, Czech Republic, Greece, Italy, Lithuania, Norway, New Zealand, Poland, Portugal, Slovenia and Thailand. The four countries are Canada, Sweden, South Africa and the United States.

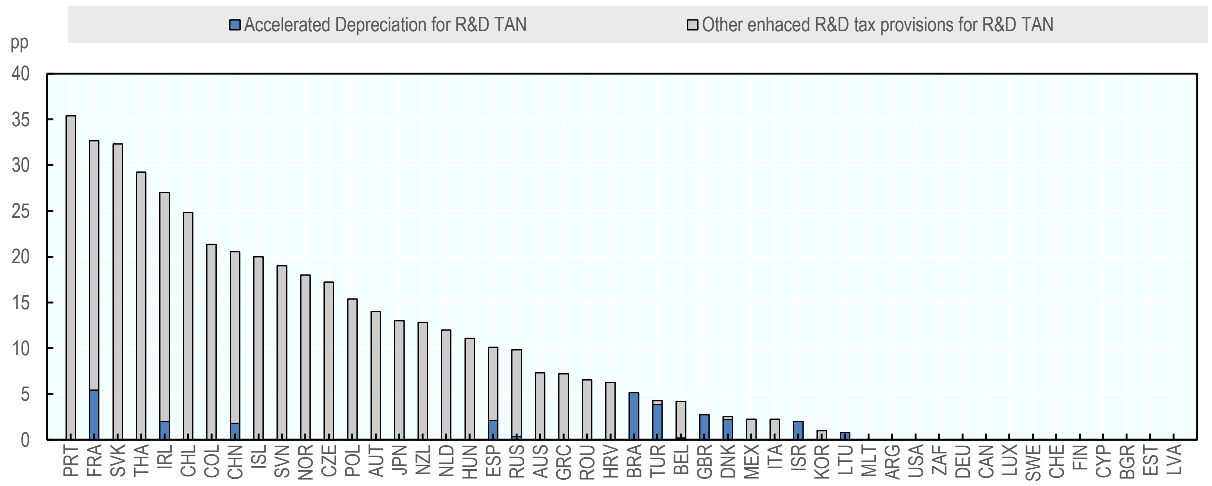
[53] A hybrid R&D tax provision combines a volume-based and an incremental component, see Section 2.

allowances typically arise when R&D tax provisions are entirely incremental, as is the case, e.g. of the R&D tax credit in Italy.

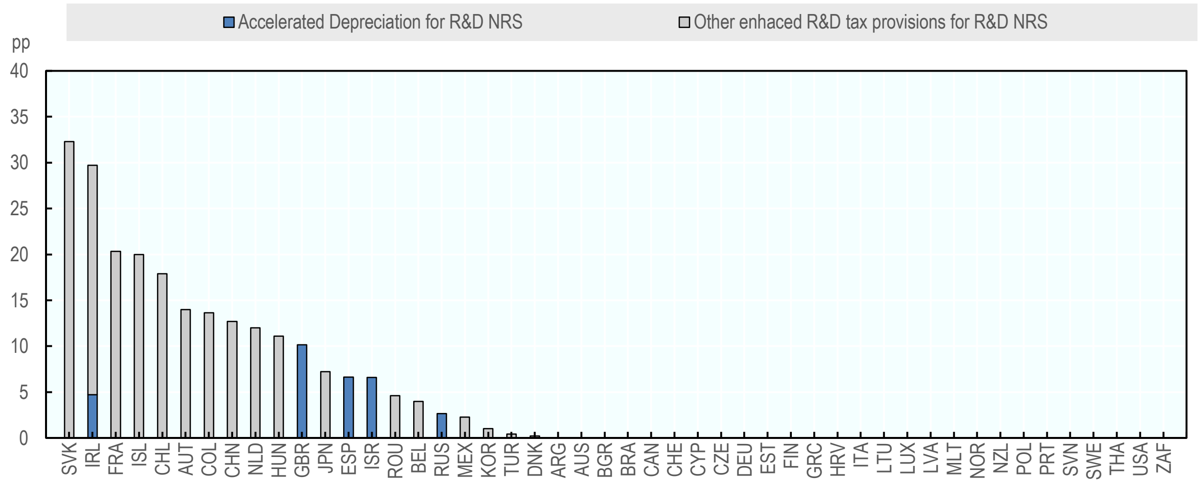
105. The preferential treatment of R&D capital expenditures can also take the form of accelerated depreciation, allowing for a faster fiscal depreciation when the capital investment is made for R&D purposes. Figure 10 splits the difference in capital allowances in Figure 9 between the contribution of accelerated depreciation and other R&D tax incentives.[54]

Figure 10. Differences in tax allowances for R&D vs. non-R&D capital, by type of incentive

Panel A: Capital expenditure – Tangible assets



Panel B: Capital expenditure – Non-residential structures



Source: OECD Secretariat calculations.

106. Accelerated depreciation is offered for all types of capital expenditure in Ireland, Israel, Spain, the United Kingdom and the Russian Federation; and for machinery and equipment in Belgium, Brazil, China, Denmark, France, Lithuania and Turkey. Accelerated depreciation is often combined with other R&D tax

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[54] This can be ascertained by breaking down the difference in the value of capital allowances between an R&D and non-R&D project. The difference in tax allowances due to accelerated depreciation can be obtained as $\Delta A^{acc} = \tau(Z - Z^{acc})$. The enhanced treatment due to other R&D tax provisions can be estimated as $\Delta A^{other} = A^{R\&D} - A^{acc}$. Note that when there is an R&D tax credit or allowance that applies to the value of depreciation allowances and the latter is accelerated, the impact of the tax credit will be captured by the change in other enhanced provisions.

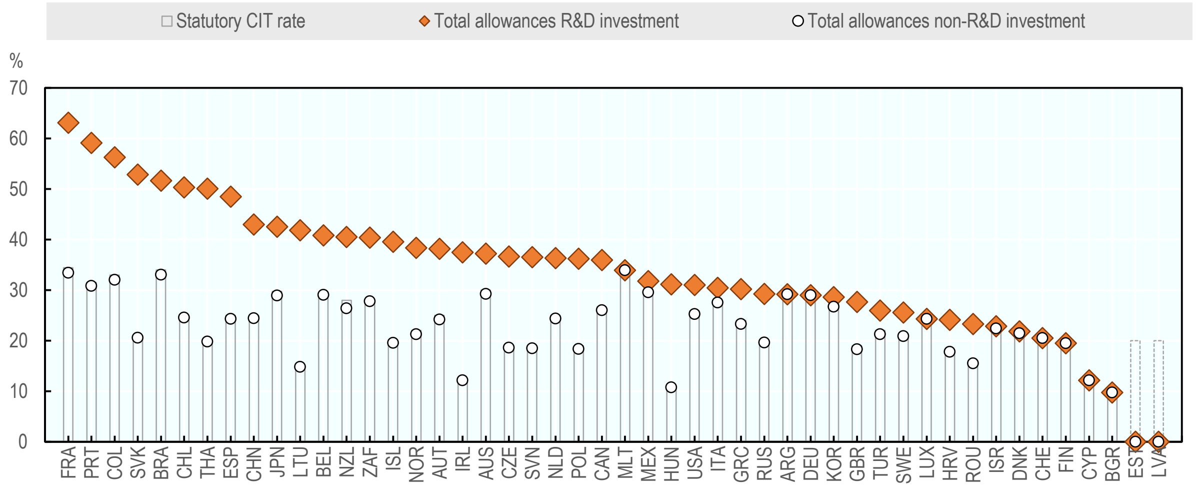
provisions, increasing even further the generosity of the incentives. This is the case in Ireland for all capital expenditure, and in Belgium, China, Denmark, France, the Russian Federation, Spain and Turkey for capital expenditure on tangible assets.

6.2. Total tax allowances for an R&D investment

107. In order to assess the generosity of R&D tax provisions in a cross-country comparison, the value of total tax allowances for an average R&D investment is compared with the corresponding value for an equivalent non-R&D investment. As for specific R&D inputs (i.e., current and capital expenditures) in Section 6.1. , this section compares total tax allowances associated with an R&D and an equivalent non-R&D investment, using the same input-composition (i.e., 90% current and 10% capital expenditure), aggregating up the input-specific tax allowances.[55]

108. Since the average R&D investment considered in this analysis is composed mostly of current expenditure, which is typically expensed, the value of tax allowances for non-R&D investments aligns closely with the statutory CIT rate in Figure 11 (i.e., the circle almost overlaps with the bar).[56] Similarly, the variation in total tax allowances for an R&D investment is largely driven by the extent of tax relief provided to current expenditure. As before, the higher the value of tax allowances, $A^{R\&D}$, the more generous the tax system is in reducing the effective cost of R&D, $1 - A^{R\&D}$.

Figure 11. Total tax allowances for R&D and non-R&D related investments



Note: The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits.
Source: OECD Secretariat calculations.

109. Figure 12 shows the difference in the value of total tax allowances for R&D and equivalent non-R&D investments. The Slovak Republic, Thailand and France provide the largest preferential treatment to R&D investments, with the value of total tax allowances for current and capital expenditure used for R&D

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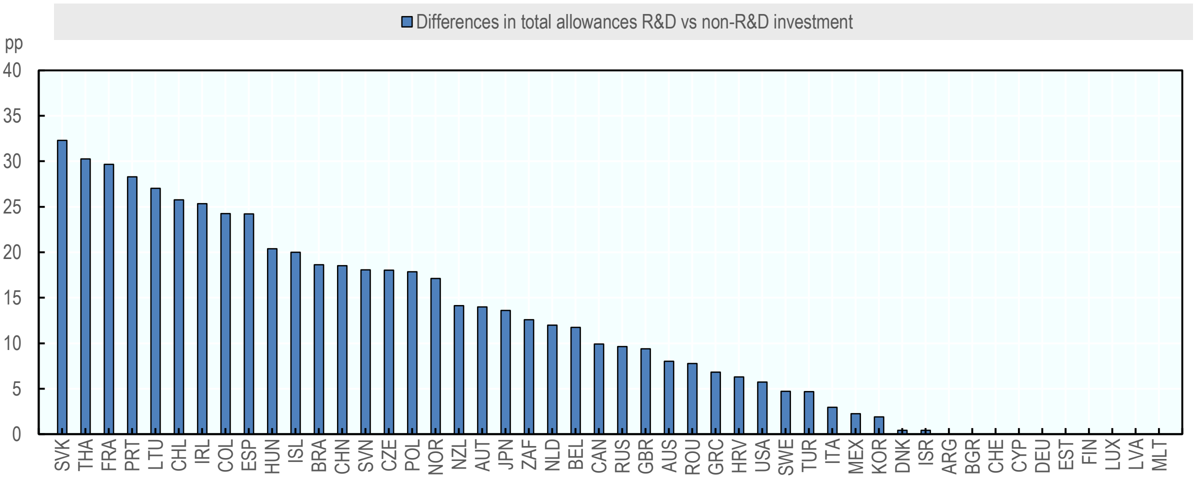
[55] Refer to Section 5.1.1. for details on this calibration and Annex D for alternative calibrations of the expenditure mix.

[56] The circle lies slightly lower than the statutory CIT rate (i.e., the top of the bar) due to the impact of the tax allowances on the capital inputs that carry a 10% weight in the overall R&D investment (see Section 5.1.1.). As shown in Panel B and C of Figure 7, the depreciation of the investment is typically deductible yielding a net present value of depreciation lower than the value of the investment due to the impact of discounting. This entails that the net present value of depreciation allowances resulting from multiplying the net present value of depreciation by the statutory CIT rate is lower than the statutory CIT rate (i.e., the base case that corresponds to full expensing).

investments being around 30 percentage points higher compared to the standard tax treatment of these inputs. This finding can be interpreted as a reduction in the effective cost of R&D investments by around 30 percentage points. Among countries offering R&D tax incentives, the unweighted average increase in total tax allowances for the R&D investment with respect to a comparable non-R&D investment equals 14.6 percentage points.

Figure 12. Differences in total tax allowances for average R&D and non-R&D investments



Note: The effect of R&D tax incentives is measured as difference in the value of total tax allowances of R&D and non-R&D investments reported in Figure 11.
Source: OECD Secretariat calculations.

110. The variability in the generosity of tax allowances across countries exhibited in Figure 12 translates into cross-country differences in the cost of capital and ETRs faced by firms investing in R&D. As discussed above, these differences can affect firms' incentives to increase their R&D investment and locate their R&D functions in a given location.

6.3. *Effective tax rates for R&D investments*

111. This section presents estimates of the cost of capital and EATRs for an R&D investment composed of a mix of 90% current and 10% capital expenditure (see Section 5. for details on the empirical calibration and Annex D for a robustness of these results to alternative calibrations of the investment). To do so, it incorporates the value of total allowances for an R&D investment, $A^{R\&D}$, calculated by mapping this fixed expenditure mix into the estimation of the ETRs (see equation (13), Section 6.2.). ETRs are also calculated for a comparable non-R&D investment based on the value of total tax allowances that would be available on current and capital expenditures in this case, $A^{NR\&D}$ (Section 6.2.)

112. The extent of the preferential treatment for R&D investments is computed as the difference with respect to the standard tax treatment that a comparable non-R&D investment would obtain. This approach provides a within-country assessment of the extent of preferential tax treatment provided to R&D investments. A comparison of country positions in the ranking provides insights about the relative generosity of the preferential treatment provided to R&D investments across countries.

6.3.1. Cost of capital for R&D investments

113. Figure 13 displays the cost of capital for an R&D and comparable non-R&D investment (Panel A), represented by the diamond and circle respectively. The cost of capital highlights the impact of taxation on

a marginal investment project. The real interest rate is displayed for reference, as the cost of capital equals the real interest rate when corporate taxation has a neutral effect on R&D-related investments.

114. As the R&D and comparable non R&D investment studied is assumed to consist of 90% current expenditure, the cost of capital for non-R&D investments (i.e., the circle) is close to the real interest rate (i.e., the light-shaded bar) in most of the countries considered. The reason for this finding is that current expenditure is typically allowed to be immediately expensed and full expensing is one of the mechanisms that supports the neutrality of the tax system, i.e., leaving investment decisions unaffected by the taxation of the marginal investment. In most cases, the cost of capital is slightly above the real interest rate due to the tax treatment of capital inputs, typically depreciated over time (see Section 6.1.)[57]. In the case of Belgium, Brazil, Cyprus, Italy, Malta, Poland, Portugal and Turkey, the lower cost of capital in the baseline is explained by the allowance for corporate equity (ACE) (OECD, 2020[40]).

115. R&D tax incentives effectively lower the cost of capital; this can be seen in Figure 13 (Panel A) where diamonds are placed below the circles, corresponding to the case where $\tilde{\rho}^{NR\&D} > \tilde{\rho}^{R\&D}$. The figure also shows that for 36 out of the 38 countries that have R&D tax incentives in the sample, the cost of capital for R&D investments is below the real interest rate, r; this result corresponds to case 2, illustrated in Figure 5, where $\tilde{\rho} > r > \tilde{\rho}^{R\&D}$. The driving force behind this result is the large role of current expenditure in the composition of the R&D investment considered in this analysis. As the cost of capital in the comparable non-R&D investment is only just above r, the enhanced tax deductions for R&D lower the cost of capital below the real interest rate.

116. In this calibration, Denmark and Israel, however, fall into case 1 where $\tilde{\rho} > \tilde{\rho}^{R\&D} > r$, illustrated in Figure 4. In these countries, R&D tax incentives lower the cost of performing the R&D investment vis-à-vis a comparable non-R&D investment, but the firm still needs to realise a higher pre-tax return than in the absence of taxation in order to break even on a marginal investment project. This result stems largely from the fact that, for Israel, the R&D tax incentive consists of accelerated depreciation applicable only to capital inputs. In Denmark, although the R&D tax allowance applies to current expenditure, the extent of the relief granted is quite modest, with a headline tax allowance rate of 1.5%. This means that for current expenditure, the net present value of allowances is in this case just above the statutory CIT rate (A^{C}=22.33% as per Figure 6). For capital inputs, accelerated depreciation is available, however, as in the case of Israel, the corresponding tax relief does not increase the value of tax allowances above the statutory CIT rate.

117. These findings suggest that several governments grant tax subsidies to R&D investments based on the empirical calibration discussed above. Among the countries offering R&D tax incentives, 16 countries (Panel A) still achieve a positive cost of capital for R&D investments, while for another 22 countries the generosity of the incentives drives the cost of capital into the negative domain for the investment considered. In the eight remaining countries, the absence of tax incentives[58] means that $\tilde{\rho} = \tilde{\rho}^{R\&D}$, shown as an overlay of circles and diamonds in Figure 13 (Panel A).

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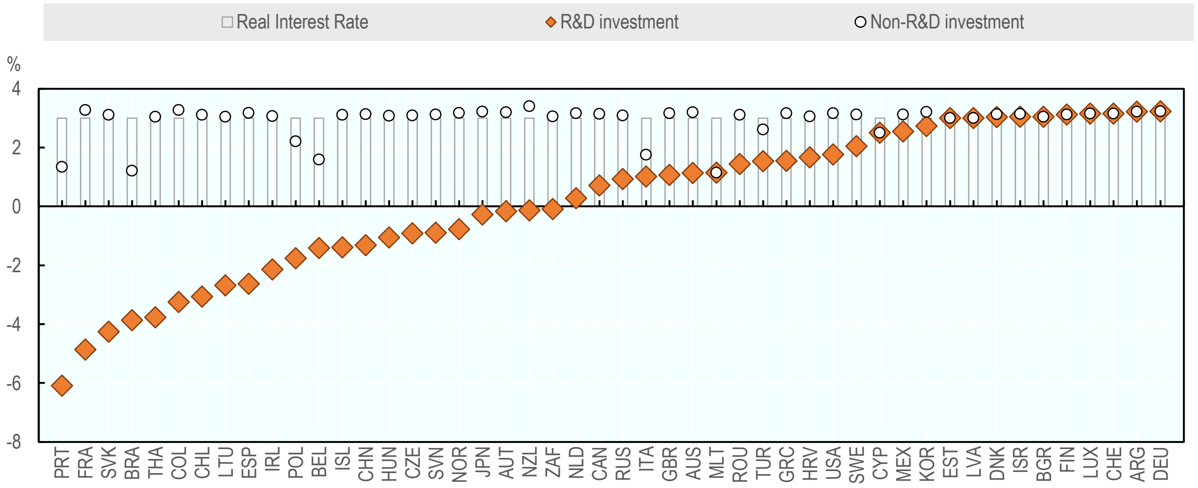
[57] In most countries, it is the depreciation of the capital investment that is allowed deduction. Expensing provisions as the general treatment, i.e. non-R&D specific, are uncommon, but would play the same role as expensing provisions for current expenditure. One example of this type of provisions would be the 2018 US tax reform –to be modelled in the future version of this paper. As explained in Section 6.1. , the comparison point for the generosity of the fiscal treatment of capital investments is usually the economic depreciation of the asset. Further interpretation of the capital-specific ETRs is not pursued here as they serve as inputs to the R&D investment, not as investments in themselves. For capital-specific investments, see (Hanappi, 2018[19]).

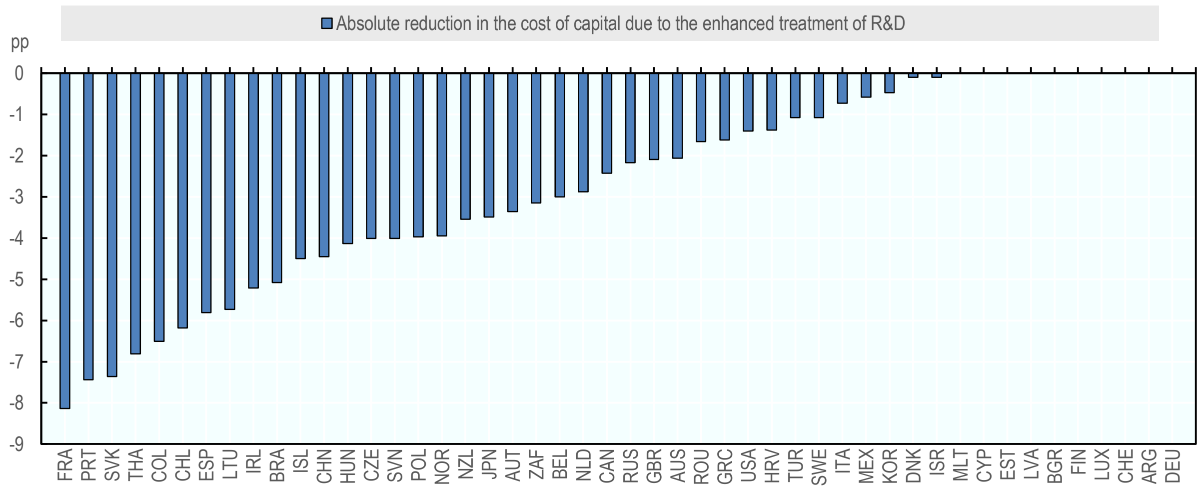
[58] For large profitable firms. Denmark and New Zealand offer R&D tax incentives for loss-making firms that are not captured in this scenario. More generally, provisions such as carry-overs and refunds are not modelled due to the consideration of a large profitable firm. Note that Malta does have R&D tax incentives but these have not been

Figure 13. Cost of capital of R&D and non-R&D investments

Panel A: Estimates of the cost of capital for R&D and non-R&D investments (percentages)



Panel B: Effect of R&D tax incentives on the cost of capital (percentage points)



Note: The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits. The effect of R&D tax incentives (Panel B) is measured as difference in the cost of capital (pp) for R&D and non-R&D investments reported in Panel A.
Source: OECD Secretariat calculations.

118. Portugal**,** France and the Slovak Republic are the countries offering the most generous treatment to marginal R&D investments, providing greater incentives to increase the volume of R&D investment. The least generous treatment among countries offering R&D tax support is observed in Denmark, Israel and Korea. As anticipated, the large cross-country variability in the preferential treatment provided to R&D expenditures, translates into a wide variability in the cost of capital of R&D investments across countries (see Figure B.3 for the distribution of estimates). The unweighted average cost of capital among countries that offer R&D tax incentives is around -0.5%, with the maximum cost of capital at 3.04% and the minimum at -6.1%, represented by Israel and Portugal respectively.

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modelled due to their limited uptake. This means that in the chart the value of the cost of capital with and without R&D would be the same, $\tilde{\rho} = \tilde{\rho}^{R\&D}$.

119. The absolute difference between the cost of capital for an R&D investment and a comparable non-R&D investment (Figure 13, Panel B), $\tilde{\rho}$ and $\tilde{\rho}^{R\&D}$, gives a *within*-country indication of the magnitude of R&D tax relief to marginal R&D investments, net of the standard tax treatment. The extent of the reduction is explained by the generosity of R&D tax incentives, reflected in the value of total allowances estimated in Section 6.2. The largest reductions in the cost of capital for R&D investments are granted in France (~8 percentage points) and Portugal, the Slovak Republic and Thailand (~7 percentage points). The average reduction in the cost of capital for R&D investments among countries offering R&D tax incentives is 3.5 percentage points[59], with the smallest reduction observed in Denmark and Israel (-0.1 percentage points) (see Figure B.3 for the distribution of estimates).[60] Differences in the ranking of countries in Panel A and Panel B are explained by the fact that Panel A reflects the generosity of the standard tax treatment available to *all* investments and the preferential tax treatment to R&D, while Panel B, by taking the difference between the tax treatment of an R&D and non-R&D investment isolates the impact of R&D tax incentives.

6.3.2. Effective Average Tax Rates for R&D investments

120. Figure 14 presents the EATR of an R&D investment and a comparable non-R&D investment (Panel A), represented by the diamond and the circle respectively. The EATR represents the impact of taxation on an inframarginal investment project. In this calibration, both investments are assumed to have a private rate of return (i.e., a pre-tax rate of return) of 30% (see Section 5. for details on the empirical calibration and Annex E for a robustness of these results to alternative calibrations of the investment). The statutory CIT rate, is displayed for reference, as the EATR will equal the statutory CIT rate when the tax system is neutral to the investment decision.

121. EATRs for a non-R&D investment (i.e., the circle) are close to the statutory CIT rate (i.e., the transparent bar), due to the large share of current expenditure in the overall expenditures associated with the average R&D investment used in this calibration (see Section 5.1.1). Whether the EATR lies above or below the statutory CIT rate in the case of the non-R&D investment depends solely on the fiscal treatment of capital inputs.

122. The presence of R&D tax incentives decreases the EATR as R&D tax incentives seek to reduce the effective cost of the R&D investment, as indicated in the cases where the diamonds are situated below the circles. The extent of the reduction is driven by the generosity of the tax incentives and their interaction with other elements of the CIT system.

123. Comparing the EATRs for R&D investments across countries (Panel A in Figure 14) gives insights into the attractiveness of these countries for discrete inframarginal investments (e.g., the location of R&D laboratories) from a tax perspective. In this calibration, the lowest EATRs for R&D investments are observed in Ireland, Lithuania and Hungary, for which the EATRs for R&D investments are estimated to range between -2% and -4%. This result indicates that in these locations tax subsidies are granted to inframarginal R&D investments, although to different extents.

124. On the contrary, the highest EATRs for R&D investments among countries offering tax support are estimated for Mexico, Korea and Australia. The average EATR for R&D investments for countries with R&D tax incentives is 12.5%, with the maximum (25.92%) and minimum (-3.75%) rate recorded for Mexico and Ireland respectively (see Figure B.3 for the distribution of estimates).

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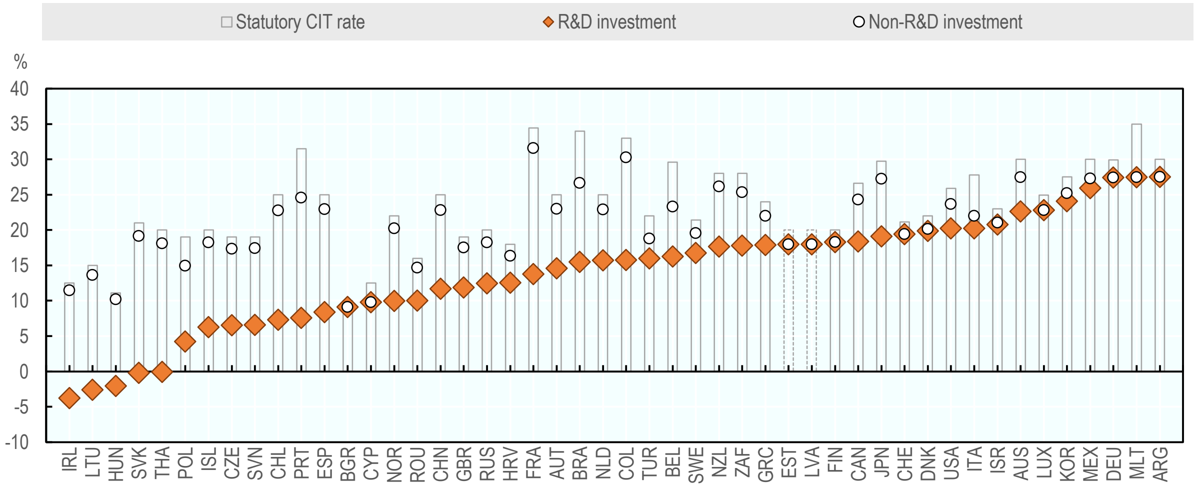
[59] For reference, the average cost of capital for those offering R&D tax incentives excluding the impact of R&D tax incentives equals 3%.

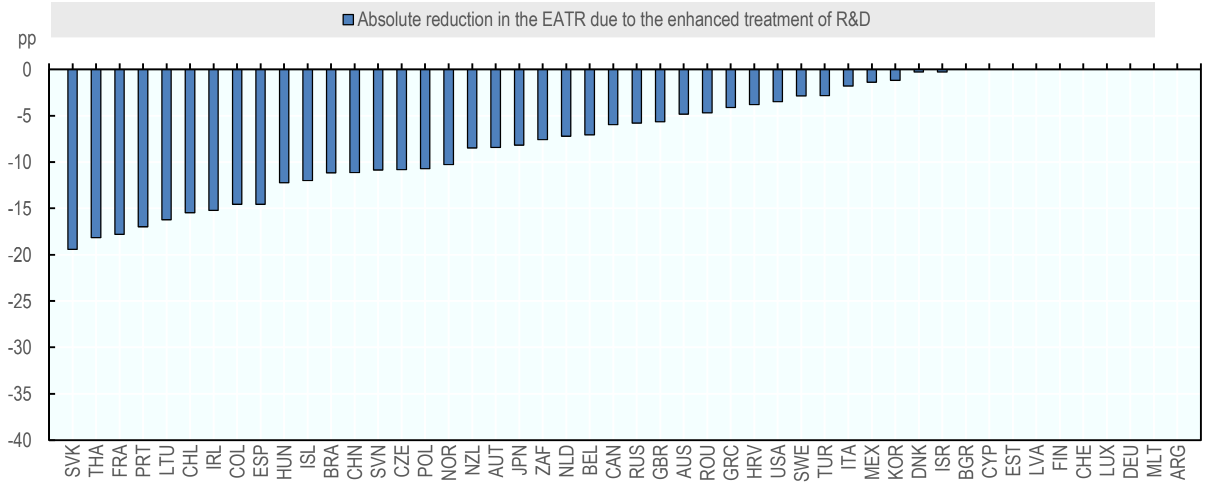
[60] This is explained by the fact that the tax support for R&D is only offered for capital inputs in Israel and the tax incentive for current expenditure in Denmark is relatively modest (see Figure 6 and Figure 7).

Figure 14. Effective Average Tax Rate on R&D and non-R&D investments

Panel A: Estimates of the EATR for R&D and non-R&D investments (percentages)



Panel B: Absolute effect of R&D tax incentives in the EATR (percentage points)



Note: The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits. The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits. The pre-tax rate of return on the investment is set to 30% in these calibrations (see Section 5. for further information on the calibration and modelling assumptions).
Source: OECD Secretariat calculations.

125. From a *within* country perspective, the highest rate of R&D tax relief, measured as the absolute difference between the EATR of comparable R&D and non-R&D investments (Panel B in Figure 14), is granted in the Slovak Republic followed by Thailand and France. The average reduction in the EATR for R&D investments among those that offer tax incentives is 8.8 percentage points[61], with the highest reduction observable for the Slovak Republic at 19.4 percentage points and the lowest reduction at -0.26 percentage points in Denmark and Israel.

126. Note that the order of Panel B does not necessarily need to align with the ordering of Panel A. This is because the position of countries in Panel A is reflective of the combination of the standard tax treatment available to *all* investments plus the preferential treatment to R&D, while Panel B, by taking the difference to the standard tax treatment captures exclusively the impact of the preferential tax treatment of R&D investments. If a country offers a generous tax treatment to investment overall, but not specifically to R&D, it would be ranked towards the left in Panel A and towards the right in Panel B.

127. When comparing Panel A in Figure 13 and Figure 14, it is straightforward to observe that the ranking of countries in terms of tax support for marginal investment (Figure 13) projects does not necessarily align with the ranking of countries that offer the most generous tax treatment to inframarginal investment projects (Figure 14). For instance, the top three most generous countries based on the cost of capital in this calibration are Portugal, France and the Slovak Republic, while the top three most generous countries in terms of EATRs for R&D are Ireland, Lithuania and Hungary. Aside from the generosity of R&D tax incentives, other elements of the tax system, namely the statutory CIT rate, play a substantial role in determining the overall attractiveness of countries for inframarginal investments from a tax perspective.

128. In order to shed light on the mechanisms behind this result, the EATR is split according to equation (6) into the tax liability on the marginal investment project, i.e., the first component, and the tax liability on the economic profits of the inframarginal investment project, i.e., the second component (Figure 15). As in equation (6), both components of the total tax liability are expressed as a percentage of the pre-tax rate of return. The sum of the two components yields the EATR for R&D investments as defined in equation (5)[62], which in turn matches the EATRs displayed in Figure 14.

129. The tax liability accruing on the marginal investment project, represented by the blue bar in Figure 15, is given by the difference between the cost of capital and the real interest rate. The first component of the total tax liability of the inframarginal investment project takes on a negative value in 36 of the 38 countries with R&D tax incentives. These countries fall into case 2 (see Figure 5 in section 3.2. and section 6.3.1.) where the cost of capital for R&D investments is below the real interest rate. For Denmark and Israel, as they fall in case 1, the first component in the total tax liability of the marginal investment project is positive. In countries that do not offer R&D tax incentives this first component is also positive.

130. The second component in equation (6) captures the taxation of economic profits, represented by the light blue bars in Figure 15. Economic profits, taxed at the statutory CIT rate, are given by the difference between the pre-tax rate of return, fixed at 30% in this calibration, and the cost of capital for R&D investments. The lower the cost of capital or, in other words, the more generous the treatment of the

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[61] For reference, the average EATR for those offering R&D tax incentives excluding the impact of R&D tax incentives equals 21.3%.

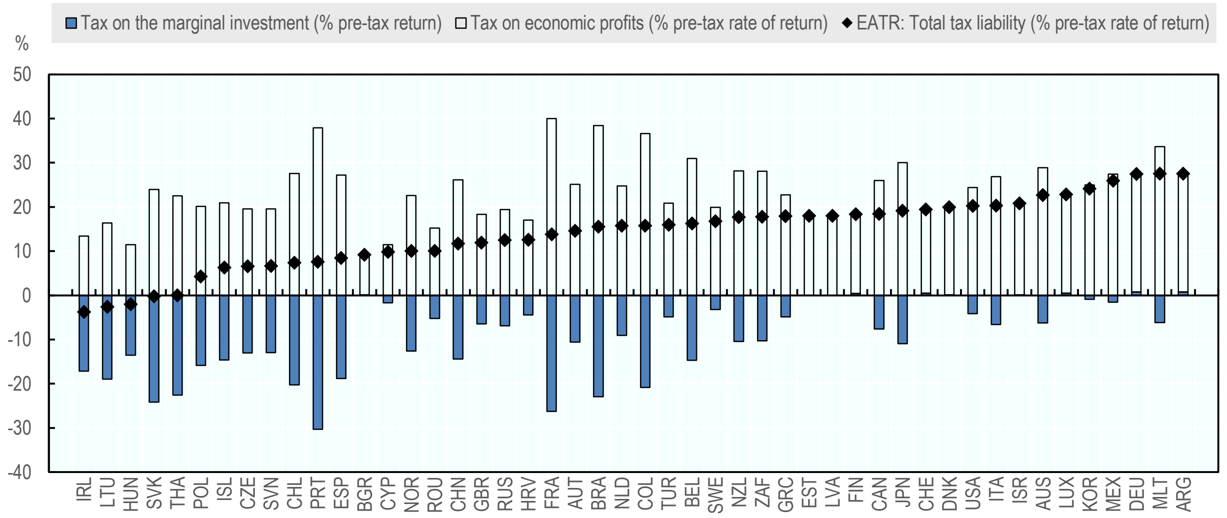
[62] Note that for Estonia and Latvia where profits are taxed when they are distributed an adjustment in the EATR calculation is required. This form of taxation is modelled through the parameter γ that measures the opportunity cost of retained earnings in terms of foregone (gross) dividends, see Hanappi (2018[19]). The EATR in equation (5) accounting for this parameter will be given by $EATR = {\tilde{p} - r + (p - \tilde{p})(1 - \gamma(1 - \tau))}/{p}$.

For the rest of countries, γ is equal to 1 since dividend and capital gains taxation are not taken into account and thus this equation boils down to equation (5) in the main text. For Estonia and Latvia this parameter takes a value of 0.8, see (OECD, 2020[40]).

marginal R&D investments, the larger the size of the economic profits associated with the investment project[63]. The higher the statutory CIT rate is at which economic profits are taxed, the higher the second component of the total tax liability will be. The total tax liability on inframarginal R&D investments, and thus the effective tax liability on a profitable investment project, depends on the sum of the two components.

Figure 15. Decomposition of the tax liability on an inframarginal R&D investment

Components of the tax liability on an inframarginal investment



Note: The tax on the marginal project is calculated as $\tilde{p} - r$; the tax on the economic profit is expressed as $\tau(p - \tilde{p})$ following equation (6). The sum of the two components represent the tax liability on the inframarginal investment which, divided by the pre-tax rate of return p yields the EATR.
Source: OECD Secretariat calculations.

131. In some countries that grant a generous treatment to the marginal investment project the total tax liability on inframarginal R&D investments is still comparatively high because a proportion of economic profits is subject to comparatively high statutory CIT rates. This is the case, e.g., in France, Brazil, Colombia and Portugal, countries that all have statutory CIT rates between 30% and 34%. However, countries with lower statutory CIT rates, which provide similar levels of tax relief on marginal investment projects, end up with a comparatively lower total tax liability on inframarginal R&D investments, due to a much lower second component. This means that for those countries with comparatively lower statutory tax rates, e.g., Ireland, Lithuania or Hungary, the tax liabilities raised on economic profit do not offset the tax subsidy granted on marginal investment projects. As a consequence, the EATR ends up being negative, implying an overall subsidy to the inframarginal R&D investment considered in this empirical calibration.

132. Considering a project with higher profitability, however, would imply increases in the EATR across the board. This is due to the greater prominence of the second component, associated with economic profit, in the total tax liability, which is taxed at the statutory CIT rate. The cost of capital, by definition, remains invariant to changes in the profitability of the investment project, as it refers to the marginal case. Annex E provides a sensitivity analysis around different assumptions on the profitability of the investment project.[64] In this calibration, the investment is assumed to be financed by retained earnings. Considering

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[63] This can be seen in Figure 2. As the cost of capital decreases, the area drawn as $pFG\tilde{p}$ representing the economic profit would consequently increase given a fixed pre-tax rate of return, p.

[64] Note that as the pre-tax rate of return tends to infinity, the EATR will approximate the statutory CIT rate.

debt financing, ETRs would be typically lower across the board due to the deductibility of interest payments, except for countries where ACE provisions are in place.

133. Overall, a more generous tax treatment towards marginal compared to inframarginal investments, as observed, e.g., in Portugal, France or Colombia, creates higher incentives for R&D investments at the intensive margin. This suggests that R&D tax incentives support primarily increases in R&D investment for firms already located in the respective country. In contrast, if a comparatively generous tax treatment is granted to inframarginal investments, as is the case, e.g., in Ireland, Lithuania and Hungary, the tax system offers relatively strong support for R&D investments at the extensive margin, i.e., creating incentives for the location of new R&D investment in the respective country.

134. These results provide evidence on the incentive that the tax system grants to firms investing in R&D, but do not provide a direct link to the R&D activity of firms, nor to the actual cost of these provisions to the government as this depends among other factors on firm uptake. This is because taxation is ultimately *one* of the factors affecting investment decisions and R&D tax incentives are only *one* of the tools governments adopt to foster R&D.

135. Most governments rely on a combination of tax and direct support measures to reduce barriers to innovation and promote R&D and innovation (Section 2.1.). Whether tax or direct support plays a larger role in the policy-mix varies across countries. Countries that are recorded as offering modest incentives to R&D investment through the tax system might have a larger reliance on direct support to promote business R&D. For instance, in the case of Mexico, Sweden and the United States – three countries that typically rank as countries offering only modest tax subsidies at the intensive and extensive margins - direct support accounts for 90% in the first two countries and 60% of total government support to business R&D, respectively in 2018 (OECD, 2021[3]). Beyond public support, other elements are crucial to create an environment that is favourable to R&D and innovation: a skilled workforce, stable macroeconomic and regulatory conditions, well-functioning product, labour and risk capital markets are all key elements in the mix (Andrews, Criscuolo and Menon, 2014[7]; OECD, 2015[1]; Bloom, Van Reenen and Williams, 2019[8]).

7. Final remarks

136. Recent years have observed an increase in the use of R&D tax incentives across countries, with their weight on public finances growing steadily over the last two decades (Appelt, Galindo-Rueda and González Cabral, 2019[6]; OECD, 2020[36]). R&D tax incentives exhibit very heterogeneous design features across countries, which come on top of the existing differences in corporate income tax rates and tax bases of their standard corporate tax systems. This creates a complex landscape and makes it difficult to assess the effective cost that firms' face across countries when making R&D investment decisions. To add to this challenge, the globalisation of the economy has led to the fragmentation of R&D activities allowing firms more flexibility to choose where to locate their R&D activity (Belderbos et al., 2016[43]; Galindo-Rueda et al., 2018[4]). This development may also lead certain governments to use tax policy to attract these activities, bringing to the fore the importance of constructing tax policy indicators that assess the cost that R&D firms face when making R&D investment decisions.

137. To enable a consistent cross-country comparison of the generosity of these incentives, this working paper presents a framework to analyse the effect of expenditure-based R&D tax incentives in firms' effective tax rates. Two synthetic indicators are derived: the cost of capital for R&D, which is useful to analyse decisions at the intensive margin, i.e. how much to invest in R&D; and the effective average tax rate for R&D, which is useful to evaluate decisions at the extensive margin, i.e. whether or where to invest in R&D.

138. The paper provides estimates for 48 countries, including all OECD countries, non-OECD EU countries and a further six selected economies. They consider the case of large firms that are profitable enough to utilise the available tax benefits, in order to analyse the incentives faced by large R&D performers, in which R&D investment is heavily concentrated (Dernis et al., 2019[18]). The extent of preferential treatment for R&D is assessed both within and across countries. *Within* countries, it is measured by the reduction in the cost of capital or the EATR for the R&D investment against a comparable investment that does not qualify for relief. *Across* country comparisons are shown in terms of the cost of capital and EATRs.

139. The results reflect a vast heterogeneity in the generosity of R&D tax incentives. Among OECD countries where they are offered, R&D tax incentives are estimated to reduce the cost of capital on average by 3.5 percentage points and the EATR firms face by 8.8 percentage points. Interestingly, the ranking of the countries providing the most favourable treatment to R&D differs between the intensive and extensive margins.[65] This is relevant in that countries providing more favourable tax treatment to profitable investments than to marginal investments offer greater incentives for the (re)location of R&D investment. In the alternate case, a greater incentive is provided for firms already located in the country to expand their R&D investment. This paper also investigates how results vary for R&D projects that have a different composition (i.e. in terms of the mix of current and capital expenditure) as well as for R&D projects with different private rates of return to R&D.

140. The indicators of the cost of capital and effective tax rates for R&D presented in this paper shed light on the heterogeneity of the generosity of tax support across countries. They contribute to expand the set of tools available to policymakers and researchers to understand the impact of taxation on the extent and location of R&D investment. Future OECD work aims to continuously expand the data infrastructure to support policy analysis and research on the effect of R&D tax incentives on the R&D investment decisions of firms, and in particular those of MNEs in today's globalised R&D setting. Possible extensions include the provision of time-series estimates for the current scenario of large, profitable firms and the

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[65] For reference, the average EATR and cost of capital for R&D for those offering R&D tax incentives excluding the impact of R&D tax incentives equals 21.3% and 3% respectively.

modelling of tax relief provisions for SMEs and loss-making firms, available for the B-Index indicator. Another direction for future work could be to investigate the tax implications of cross-border investments (Grubert, 2003[44]; Devereux and Griffith, 2003[5]; Pfeiffer and Spengel, 2017[37]).

141. While this paper has concentrated on the incentives created to firms via the tax system, it is important to interpret them in conjunction with other measures of government support to have a complete picture of governments' efforts in supporting business R&D. Aside from the key role that governments play in helping firms overcome barriers to innovation, other factors such as the presence of a skilled workforce, stable macroeconomic and regulatory conditions, well-functioning product, labour and risk capital markets are all key elements that contribute to the development of an environment where innovation can thrive (Andrews, Criscuolo and Menon, 2014[7]; OECD, 2015[1]; Bloom, Van Reenen and Williams, 2019[8]).

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Annex A. ETRs: Key formulae

142. The modelling of ETRs in this paper follows the framework developed by Devereux and Griffith (2003[5]). The model considers a hypothetical two-period investment model, based on a one-period perturbation of the capital stock, by which the firm buys an asset in year 1, the asset contributes to production and generates a return during that year, and then the asset is disposed of in year 2.

143. The EATR can be calculated as the difference between the net present value of the economic profits generated by an inframarginal investment before and after tax, R and R^* respectively, scaled by the net present value of the pre-tax total income stream net of depreciation, p, and discounted using the real interest rate, r [66]

$$EATR = \frac{R^* - R}{p/(1+r)} \tag{A.1}$$

144. The key parameter of interest in the EATR is the post-tax economic profit, R, which can be derived following the rationale of the model. A firm invests 1 unit of R&D in period t which translates into an increase in the capital stock of 1 unit. The cost of the investment to the firm is, however, reduced by the provisions established in the tax system that include both the baseline treatment of expenses and the enhanced treatment of R&D when available. All tax allowances, baseline and enhanced, provisioned by the tax system are summarised in the term A. Therefore, the first term in the equation, $1 - A$, represents the net cost of one unit of physical investment in period t where A represents the net present value of tax allowances per unit of investment.

145. This investment is expected to generate a positive return in period $t + 1$, where p represents the pre-tax rate of return and δ the (one-period) economic depreciation rate. In period $t + 1$, there is a disinvestment that returns the value of the capital stock to the initial level; this disinvestment is captured by the last term in equation (A.2). Considering the case of retained earnings and in the absence of personal taxation[67], the post-tax economic profit is given by:

$$R = \underbrace{-(1-A)}_{\text{Investment}} + \frac{1}{1+r}\Big[\underbrace{(p+\delta)(1-\tau)}_{\substack{\text{Returns generated}\\ \text{by the investment}}} + \underbrace{(1-\delta)(1-A)}_{\substack{\text{Reduction in the}\\ \text{capital stock}}}\Big]. \tag{A.2}$$

146. EMTRs measure the tax liability on marginal investments, i.e., on investments with a post-tax economic profits of zero. EMTRs are used to evaluate decisions on the intensive margin, e.g., the expansion of investment in R&D in a certain location.

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[66] A natural choice of normalising the rate would be scaling using the pre-tax economic rate of return, R^*. However, this would not allow for the EATR to be defined in the cases where the post-tax economic rate of return is equal to zero. Thus the discounted value of the income stream as a normalising variable.

[67] Taxation at the individual level and taxation of capital gains and the impact of alternative sources of finance affect the calculation of the ETRs, see Hanappi (2018[19]).

147. The user cost of capital net of depreciation, $\tilde{p}$, —instrumental in estimating EMTRs— is defined as the pre-tax real rate of return necessary to generate a zero post-tax economic profits. Therefore, setting R equal to zero in (A.2) and solving for the pre-tax rate of return yields a definition of $\tilde{p}$.

$$\tilde{p} = \frac{(1-A)(r+\delta)}{(1+\pi)(1-\tau)} - \delta \qquad \text{(A.3)}$$

148. An expression for the tax inclusive and tax exclusive EMTR can be derived respectively as follows:

$$EMTR^I = (\tilde{p} - r)/\tilde{p}\,; \quad EMTR^E = (\tilde{p} - r)/r \qquad \text{(A.4)}$$

149. The B-Index, a related indicator reflecting the extent to which the tax system reduces the effective cost of the investment to the firm, can likewise be obtained as follows.

$$B\text{–}Index = \frac{1-A}{1-\tau} \qquad \text{(A.5)}$$

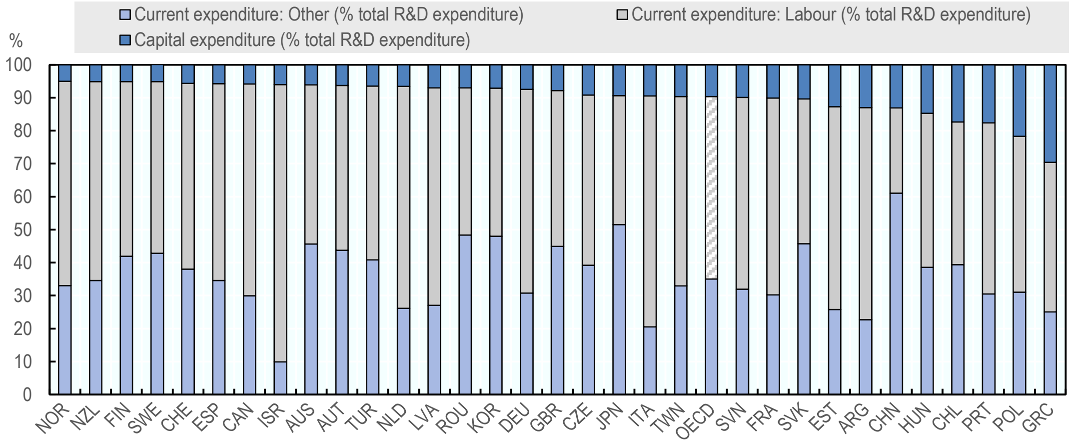
Annex B. Supplementary R&D statistics and additional results

150. This annex presents statistics on the cost composition of an R&D across countries. This composition forms the basis for the estimation of ETRs as discussed in Section 5.1.1. . Figure B.1 shows the R&D expenditure-mix for selected OECD and partner economies for which data are available and Figure B.2 plots the distribution of the expenditure mix for OECD countries for which data are available.

151. As shown in Figure B.1, the cost composition of intramural R&D varies across countries. In all cases, R&D investments are characterised by a heavy weight of total current vs capital expenditure, as is visible in the first box plot in Figure B.2. In fact, looking at the distribution of current in total R&D expenditure, for the top 25% of OECD countries, current expenditure represents up to 95% of total R&D expenditure, and for the bottom 25%, 89.7% of total R&D expenditures (i.e., in third and first quartile, respectively). The mean, represented by the asterisk in Figure B.2, is around 90%, with the median slightly higher. The share of labour costs varies more across OECD countries, as shown in the second box plot. Ranked by the share of labour costs in current expenditure, for the top 25% of the distribution, labour costs represent more than 67% of total current costs, while representing less than 54% of total current costs for the bottom 25% of the distribution (i.e., in third and first quartile, respectively). The whiskers in both graphs mark the top and bottom 10% of the distribution (cf. Table B.1 for additional statistics).

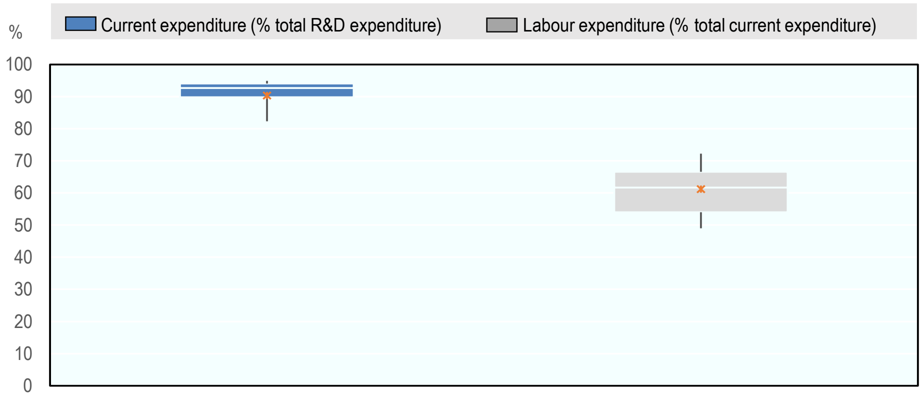
Figure B.1. Intramural R&D expenditure, by type of cost

OECD countries and selected economies



Note: The OECD label in the chart shows the unweighted average of the distribution of R&D expenditure across OECD countries, which include Australia, Austria, Canada, Switzerland, Chile, Czech Republic, Germany, Spain, Estonia, Finland, France, United Kingdom, Hungary, Israel, Italy, Japan, Korea, Latvia, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, Slovenia, Sweden and Turkey. Data for the remainder of OECD countries were not available for this indicator. The graph also cover four partner economies: Argentina, China, Chinese Taipei and Romania.
Source: OECD Secretariat, based on the Research and Development Statistics database http://oe.cd/rds, October 2020.

Figure B.2. The distribution of the R&D expenditure mix in OECD countries



Note: The box delimits the 25th and 75th percentile, the line the 50th percentile (median), the top whisker represents the 90th percentile, the bottom whisker represents the 10th percentile and the asterisk the mean of current and labour expenditure (% total R&D expenditure). This chart covers the following OECD countries: Australia, Austria, Canada, Switzerland, Chile, Czech Republic, Germany, Spain, Estonia, Finland, France, United Kingdom, Hungary, Israel, Italy, Japan, Korea, Latvia, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, Slovenia, Sweden and Turkey. Data for the remainder OECD countries were not available for this indicator.
Source: OECD Secretariat, calculations based on Research and Development Statistics database http://oe.cd/rds, October 2020.

Table B.1. Additional summary statistics of intramural R&D expenditure, by type of cost

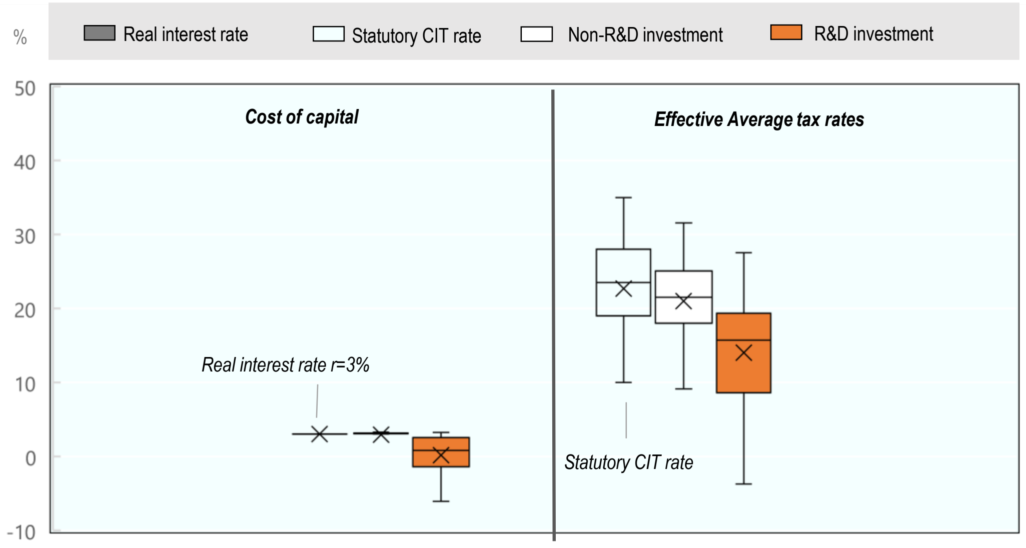
OECD countries

	N	Average	Median	75th percentile	25th percentile	10th percentile	90th percentile	Min	Max
A. Current expenditure	28	90.33	92.68	94.04	89.77	82.32	94.9	70.41	94.96
A.1 Labour		55.29	52.82	61.62	47.27	43.9	67.24	25.89	84.06
A.2 Other current		35.04	34.56	42.36	30.06	25.01	45.7	9.89	61.04
B. Capital expenditure	28	9.67	7.32	10.23	5.96	5.1	17.68	5.04	29.59
Calibration 1: Averages for the top 10% of the distribution of current to total R&D expenditure									
A. Current expenditure	28	94.94							
A.1 Labour	28	58.39							
A.2 Other current		36.52							
B. Capital expenditure		5.06							
Calibration 2: Averages for the bottom 10% of the distribution of current to total R&D expenditure									
A. Current expenditure	28	77.01							
A.1 Labour	28	48.16							
A.2 Other current		28.84							
B. Capital expenditure		22.99							

Note: This table covers the following OECD countries: Australia, Austria, Canada, Switzerland, Chile, Czech Republic, Germany, Spain, Estonia, Finland, France, United Kingdom, Hungary, Israel, Italy, Japan, Korea, Latvia, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, Slovenia, Sweden and Turkey. Data for the remainder OECD countries were not available for this indicator.
Source: OECD Secretariat, based on the Research and Development Statistics database http://oe.cd/rds, October 2020.

Additional results

Figure B.3. Distribution of estimates of the cost of capital and effective average tax rates



Note: The box delimits the 25th and 75th percentile, the line the 50th percentile (median), the bottom and top whiskers represent the points to the lower (higher) point observed at 1.5 times the interquartile range (75th-25th percentile) and the asterisk the mean. The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits. The rate of return on the investment is set to 30% in this calibration (see Section 5. for further information on the calibration and modelling assumptions). The left-hand side shows estimates for the cost of capital, and the real interest rate shown for reference in the first box plot, i.e. fixed at 3% for all countries in this calibration. The second and third box plot display estimates of the cost of capital for non-R&D and R&D investment respectively. The right-hand side reflects estimates of the effective average tax rate and follow the same logic as the right-hand side, with the statutory CIT rate distribution shown in the first box plot as a benchmark. See Section 6. for a discussion of results. Both the cost of capital and EATR distribution are shifted downwards compared to those of a non-R&D investment because of the impact of R&D tax incentives in reducing the cost of performing R&D.
Source: OECD Secretariat calculations.

Annex C. R&D tax incentives modelled

Table C.1. Expenditure-based R&D tax incentives modelled and modelling notes, 2019

Country	Modelled R&D tax provisions
Argentina	- No expenditure-based R&D tax incentives in 2019
Australia	- R&D tax credit (volume) Modelling note: The modelling considers a firm with turnover above AUD 50 million Not modelled: – 175% International Premium incremental tax concession for additional investment in foreign-owner R&D (available as of 1 July 2007)
Austria	- R&D tax credit premium (volume)
Belgium	- R&D tax credit for capital expenditures (volume) - Partial exemption of payroll withholding tax (PWHTC). - Accelerated depreciation for tangible assets for R&D.
Brazil	- R&D tax allowance - Accelerated depreciation for tangible assets used for R&D. Not modelled: - The R&D tax allowance rate may vary from 60% to 100% depending on R&D staff growth and patent/cultivar registration.
Bulgaria	No expenditure-based R&D tax incentives in 2019
Canada	- Scientific Research and Experimental Development (SR&ED) tax credit (volume) Not modelled: - Provincial R&D tax incentives.
Chile	- Tax credit for intramural and extramural R&D (volume)
China	- R&D tax allowance (volume) - Accelerated depreciation for tangible assets used for R&D
Colombia	- R&D tax credit (volume)
Croatia	- R&D tax allowance (volume) Modelling note: The R&D tax allowance is available at a rate of 100% for basic research, 50% for industrial research, 25% for experimental development and 50% for feasibility studies. An enhanced rate of 37% is modelled, applying a common 6:30:64 distribution of business R&D expenditure (BERD) by orientation of R&D performance (basic research, applied research and experimental development) based on an average estimate for OECD countries for 2008-15 (www.oecd.org/sti/rds).
Czech Republic	- R&D tax allowance (hybrid) Not modelled: Extension of qualifying expenses to include external services related to R&D provided by public R&D institutions (from January 2014).
Cyprus	- No expenditure-based R&D tax incentives in 2019.
Denmark	- Accelerated depreciation for tangible assets used for R&D. - R&D tax allowance Not modelled: - R&D tax credit (deficit-related, volume)
Estonia	No expenditure-based R&D tax incentives in 2019
Finland	No expenditure-based R&D tax incentives in 2019
France	- Crédit d'Impôt Recherche (CIR), R&D tax credit (hybrid): Modelling note: A tax credit rate of 30% apples to eligible R&D expenditures up to EUR 100 million (5% above this threshold).This threshold is assumed to be non-binding

	- Accelerated depreciation for tangible assets used for R&D. Not modelled: - The double deduction applicable to the wages of researchers with a PhD or equivalent degree and unlimited employment contract (young doctors) for the purposes of the R&D tax credit. - The exemption of social security contributions for young innovative enterprises (JEIs) or young university enterprises (JEUs).
Germany	No expenditure-based R&D tax incentives in 2019.
Greece	R&D tax allowance (volume)
Hungary	- R&D tax allowance (volume) - Exemption of social security contributions. Modelling note: The social security contribution rates amount to 20% for researchers and 9.25% for PhD students and are weighted to account for the share of R&D expenditure attributable to each group. Not modelled: – Collaboration agreements with higher education institutions, the Hungarian Academy of Sciences or research institutions established by them (300% R&D tax allowance rate). – Development tax incentive for acquisitions of intangible assets, machinery and equipment and buildings used for R&D purposes. - R&D tax credit on SSCs of R&D staff in enterprises recognized as a research facility (50%, mutually exclusive with SSC exemption), 2019Exemption and R&D tax credit in Small Business Tax (KIVA), 2019
Iceland	R&D tax credit (volume)
Israel	Scientific investment deduction: accelerated depreciation for tangible assets and non-residential structures used for R&D.
Ireland	- R&D tax credit (volume) - Accelerated depreciation for tangible assets and non-residential structures used for R&D.
Italy	- R&D tax credit (incremental). Modelling note: The base amount is defined to be the average R&D investment cost in the 2012 - 2014 period. In the model, the base amount if taken to be a three year average as an approximation. Not modelled: - The enhanced rate of 50% that applied to (i) expenses incurred with respect to R&D contracts signed with universities and research organisations as well as with independent innovative start-ups and SMEs and (ii) expenses for employees directly hired to carry out R&D activities.
Japan	R&D tax credit (volume) Modelling note: The volume-based rate can rate from 6-14% for large firms (temporarily until march 2021, usual rate ranges from 6-10% for large firms). The range depends on the percentage change in R&D expenditures relative to the past 3 year average. A rate of 14% is modelled as an upper bound of generosity. Not modelled: - The high R&D intensity tax credit (incremental) - The Open Innovation activity-based R&D tax credit (volume) for cooperative or subcontracted R&D with national R&D institutes and universities (30%), SMEs (20%, applicable since2019), R&D venture corporations (25%) or other non-public corporations (20%).
Korea	- R&D tax credit for research and human resource development (hybrid) Modelling note: For large firms, the volume-based component is modelled in 2019. Not modelled: - The position of high-potential enterprises that count with an enhanced volume-based credit rate compared to large firms. - The Growth Industry and Basic Technology tax credit (enhanced volume-based rate of 20-30% for large firms and high-potential enterprises.
Latvia	No expenditure-based R&D tax incentive in 2019.
Lithuania	- R&D tax allowance (volume) - Accelerated depreciation for tangible assets used for R&D.
Luxembourg	No expenditure-based R&D tax incentive in 2019.
Malta	Not modelled: – R&D tax credit, 2014-20 – Aid for Research and Development projects (R&D tax credit), 2017-19. - R&D tax credit for R&D and Innovation, 2017-19
Mexico	R&D tax credit (incremental)
Netherlands	Payroll withholding tax credit (WBSO)
New Zealand	- R&D tax credit (volume) Not modelled:

	- R&D tax credit (deficit-related)
Norway	Skattefunn: R&D tax credit (volume)
Poland	- R&D tax allowance (volume) Not modelled: - The enhanced allowance rate for companies with Research and Development Centre (RDC) status.
Portugal	- R&D tax credit (hybrid). Modelling note: Operating expenditures qualify up to a level of 55% of R&D wage expenditure (50% of the share of other current costs is assumed to qualify for modelling purposes).
Romania	- R&D tax allowance (volume)
Russian Federation	- R&D tax allowance (volume) - Accelerated depreciation for the tangible assets and non-residential structures used for R&D. Not modelled: - Value-added tax exemptions on R&D and property tax credits for national R&D centres and organisations implementing state-approved R&D investments.
Slovak Republic	- R&D tax allowance (hybrid) Not modelled: - R&D tax allowance for incentive recipients
Slovenia	R&D tax allowance (volume)
South Africa	R&D tax allowance
Spain	- R&D tax credit (hybrid). - Accelerated depreciation for tangible assets and non-residential structures used for R&D. Not modelled: - Enhanced volume-based credit rate for staff dedicated exclusively to R&D - Exemption of employer social security contributions for qualified R&D staff (only compatible for the R&D tax credit for innovative SMEs).
Sweden	Exemption of employer social security contributions.
Switzerland	No expenditure-based R&D tax incentives in 2019.
Thailand	R&D tax allowance
Turkey	- R&D tax allowance (incremental) - Exemption of employer social security contributions. - Accelerated depreciation for tangible assets used for R&D.
United Kingdom	- Research and Development Expenditure Credit (RDEC) for large enterprises - Accelerated depreciation provision for tangible assets and non-residential structures used for R&D.
United States	- Regular Research credit (RRC) - Alternative Simplified credit (ASC) Modelling note: A weighted average of the impact of RRC and ASC on the total value of deductions is calculated, using IRS SOI data on the credits' respective shares in total qualified R&D expenditures as a weight. The weight applicable in 2019 refer to the 2013 weights as this is the latest data available at the time of this modelling exercise. The calculation accounts for RRC claims subject to the excess base (20% tax credit rate) and 50% current R&D expenditure limitation (10% tax credit rate) and the share of qualified R&D that is eligible under the ASC (14% tax credit rate). Not modelled: - Credit for basic research conducted in universities and certain non-profit organisations - Credit for energy research

Note: This table lists expenditure-based R&D tax provisions for large firms that were available in 2019. Expenditure-based R&D tax incentives that are targeted to loss-making large firms are not modelled, referred to as deficit-related incentives in the table. The R&D tax incentives modelled and modelling features date to the information available as of December 2020.
Source: OECD Secretariat adapted from the OECD R&D Tax Incentive Database, http://oe.cd/rdtax, December 2020.

Annex D. R&D investment: Composition effects

152. R&D tax incentives may provide enhanced tax relief to current and capital expenditure used for R&D purposes. The eligibility of expenditure varies across countries, which ultimately translates into differences in the tax treatment of the R&D investment, as shown in Section 6. To isolate the impact of the tax system, the R&D expenditure mix is fixed in this analysis across countries based on OECD statistics of R&D expenditure by type of cost. More specifically, the results in the main text calibrate the R&D investment to match the average 90-10 current-capital split shown in Annex B for OECD countries (cf. Section 5.1.1.

153. However, the differential tax treatment of current and capital R&D expenditure also implies that R&D investments based on different expenditure mixes may receive different levels of tax support. This is the case when only considering the standard tax treatment of these inputs. Current expenditure is typically immediately deductible while capital is typically depreciated. For instance, Dressler et al. (2018[45]) investigate how the tax system may influence the choice of technology by its differential treatment to investment projects with different cost structures.

154. This annex analyses the impact of R&D tax incentives on ETRs for R&D investments that have different expenditure mixes. Unlike other types of investments, R&D investments are typically characterised by large share of current compared to capital expenditure (Annex B, Figure B.1 and Figure B.2). However even within this pattern, different R&D investments, even within the same firm, may rely on a different endowment of current and capital expenditure. Micro-level data would be desirable to analyse this question in more detail, but it is not publicly available across countries. To this end, some variability on the composition of R&D investments from aggregated R&D statistics is exploited to illustrate these effects.

To explore alternative calibrations for the R&D expenditure mix, the variation at the 10th and 90th percentile in the distribution of the share of current expenditure in total R&D expenditure across OECD countries is used. These percentiles are represented by the whiskers in the first box plot in Figure B.2. For the top 10% (90th percentile), current expenditure represents around 95% of the expenditure mix (with capital representing 5%), while for the bottom 10% it represents around 80% (with capital representing 20%) of total R&D expenditure.

The choice of these percentiles intends to capture some of the variability in the distribution. As the underlying data are aggregated across firms and industries, they could understate the variation in the distribution of R&D expenditure. For instance, Thomson (2017[46]) illustrates that the composition of R&D by industry in OECD countries varies, with the share of capital oscillating between 8% and 21% of total R&D expenditures. Exploring industry differences goes however beyond the scope of this paper and the calibrations presented here should be treated as illustrative of the levels of support that R&D investments bearing different expenditure compositions can obtain.

155. In order to avoid pinning the calibrations to the statistics of a single country, the weight of current and labour in total R&D investment was determined by averaging their shares observed for these magnitudes for the top and bottom 10% of the distribution of current-to-total R&D expenditure. Taking averages does not meaningfully change the weights obtained but allows smoothing over possible country-specific events affecting the data. For clarity: (1) the 10th and 90th percentile of the distribution of the weight of current expenditure in total R&D in OECD countries is determined (which already gives the value of the

weight of the capital component); (2) average the share of labour costs and other current costs in total R&D for the countries in the 10th and 90th percentile determined in (1). These statistics are contained in Table B.1.

Table D.1. summarises the two additional composition patterns of the expenditure-mix at the 10th top and bottom percentile using the statistics presented in Table B.1.

Table D.1. Alternative expenditure-mix in R&D investments, for calibration

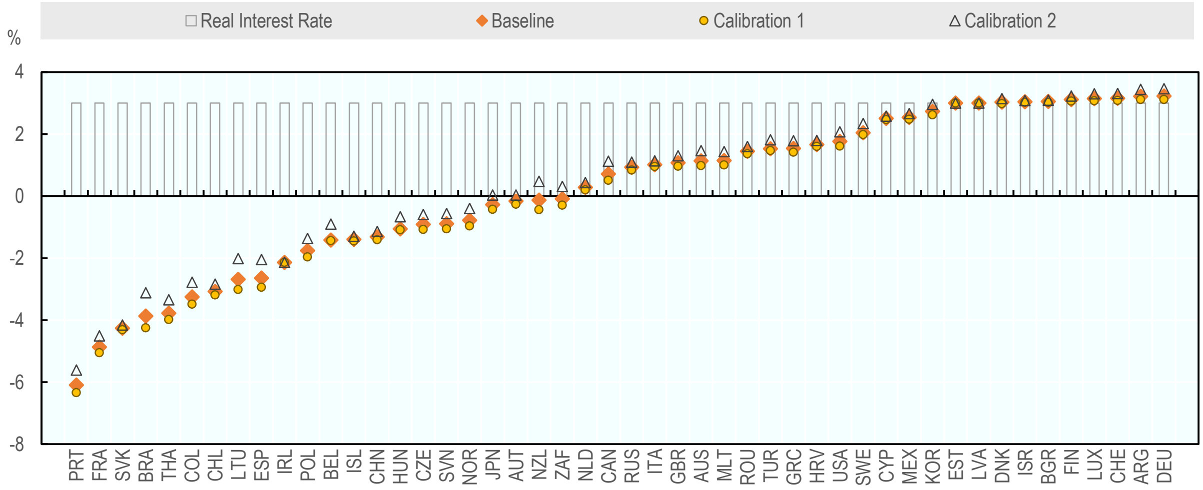
As % of total R&D expenditure	(1) Baseline (Average)	(2) Calibration 1 (90th percentile)	(3) Calibration 2 (10th percentile)
A. Current expenditure	90	95	80
A.1 Labour expenditure	60	60	50
A.2 Other current expenditure	30	35	30
B. Capital	10	5	20
B.1 Tangible assets	5	2.5	10
B.2 Non-residential structures	5	2.5	10

Note: The figures used in this table to calibrate the composition of the R&D investment in all three specifications are based on the summary statistics presented in Table B.1. Specification (1) shows the calibration underlying the results in Section 6. which are based on cross-country averages of the expenditure-mix.
Source: OECD Secretariat.

156. Figure D.1and Figure D.2 present the effect of R&D tax incentives on the cost of capital and EATR for R&D investments that have a different current-capital composition. All other assumptions on the R&D investment are maintained (see Section 5.) otherwise, the sole aspect varying across the three additional calibrations being the cost composition of the R&D investment. The results of the baseline calibration marked with a diamond reflect those presented in Section 6. The additional calibrations of the R&D expenditure mix do not have substantive effects on the estimates of the cost of capital and EATR for R&D investments. This result is driven by the fact that in all calibrations current expenditure still represents the largest proportion of total expenditure, coinciding with the range observed in cross-country aggregated data at the industry level.

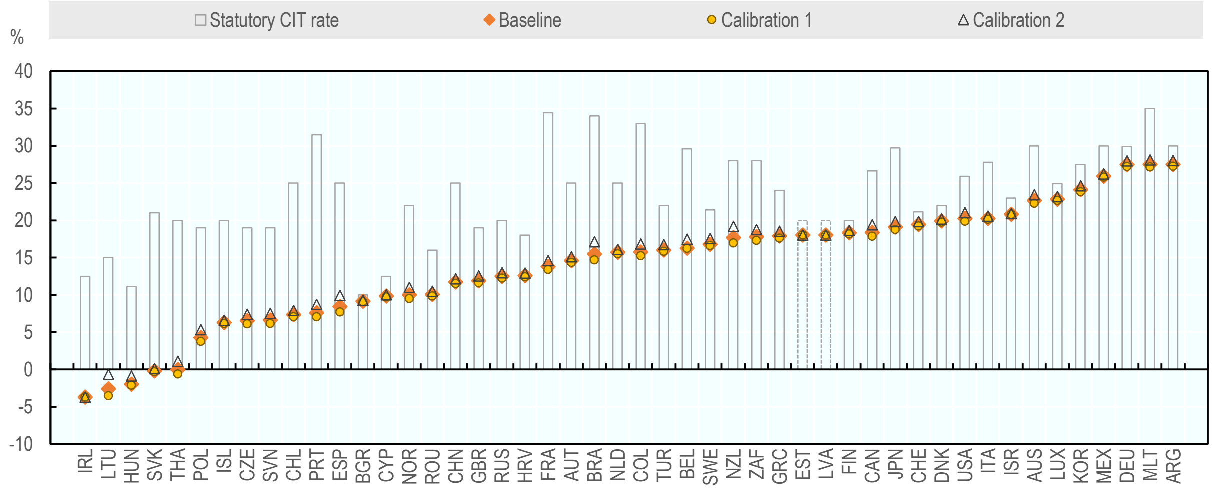
157. For calibration 2 that considers a larger weight of capital expenditure, the estimates of the cost of capital and EATRs move slightly upwards. This finding is explained by the fact that current expenditure is typically fully expensed while capital expenditure is depreciated over time, both in the baseline as outlined above (expensing versus depreciation) as well as in the case of an R&D investment where it is typically also subject to preferential tax treatment as outlined in Section 6.1.

Figure D.1. Cost of Capital of R&D investments using different expenditure mixes



Note: Countries are ordered from lower to higher estimates of cost of capital for R&D in the baseline calibration. Table D.1 contains the different expenditure mix considered in all calibrations for the current and capital components. The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits (see Section 5. for further information on the calibration and modelling assumptions).
Source: OECD Secretariat calculations.

Figure D.2. Effective Average Tax Rate on R&D investments using different expenditure mixes

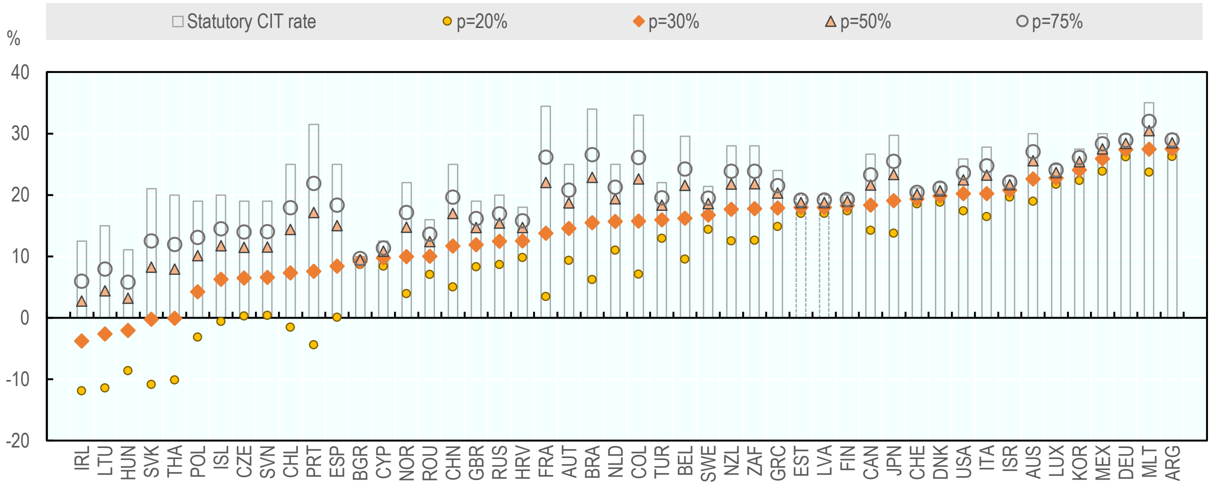


Note: Countries are ordered from lower to higher estimates of EATRs for R&D in the baseline calibration. The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits. Table D.1 contains the different expenditure mix considered in all calibrations for the current and capital components. The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits. The rate of return on the investment is set to 30% in these calibrations (see Section 5. for further information on the calibration and modelling assumptions).
Source: OECD Secretariat calculations.

Annex E. R&D investment: Alternative private rates of return

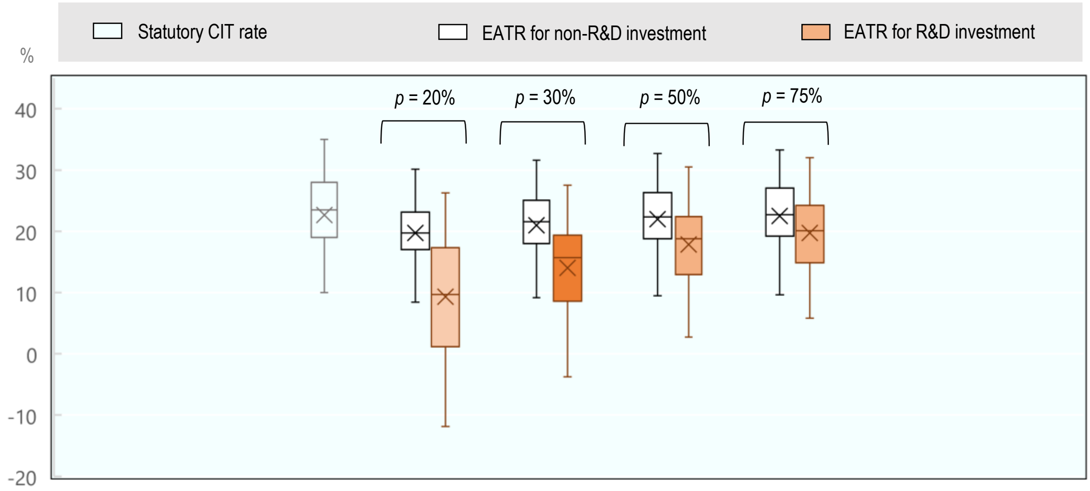
This Annex contains a sensitivity analysis to different values of the private rate of return to R&D considered. The choice of rates of return is illustrative of the ranges found in the literature, see Section 5.4.

Figure E.1. Effective Average Tax Rate on R&D investments with varying rates of return



Note: Countries are ordered from lower to higher EATRs on a project with a pre-tax rate of return equal to 30%, which is the baseline case presented in the paper (Figure 14). The statutory CIT rate in Estonia and Latvia is represented by a dashed bar as corporate income tax only applies to distributed profits. The estimates consider an R&D investment carried out by large firms that are able to fully utilise their tax benefits (see Section 5. for further information on the calibration and modelling assumptions).The figure can be analysed in combination with Figure 13. In countries where R&D tax incentives have a more acute impact on the marginal investment, increases in the pre-tax rate of return of the investment lead to greater increases in EATRs. This follows from the fact that as the pre-tax rate of return increases so does the economic profit, which is taxed at the statutory rate. Component (2) in equation (6) gains relatively more weight as the pre-tax rate of return, p, increases.
Source: OECD Secretariat calculations.

Figure E.2. Distribution of EATRs for varying private rates of return



Note: This figure reflects the distribution of EATRs for R&D and non-R&D investments with varying pre-tax rates of return to R&D (private return to R&D). The clear box plot on the left reflects the distribution of statutory CIT rates. Four private rates of return are considered: 20%, 30%, 50% and 75% illustratively, with 30% representing the baseline used to calibrate the results in Section 6. For each rate of return, the distribution of EATRs for the R&D investment (orange) is presented alongside the distribution of a comparable non-R&D investment. The distribution of EATRs for R&D investments is shifted downwards with respect to that of non-R&D investments due to the impact of R&D tax incentives in reducing the tax cost of the R&D investment. As the pre-tax rate of return increases so does the economic profit, which is taxed at the statutory rate. Component (2) in equation (6) gains relatively more weight as the pre-tax rate of return, p, increases. The box delimits the 25th and 75th percentile, the line the 50th percentile (median), the bottom and top whiskers represent the points to the lower (higher) point observed at 1.5 times the interquartile range (75th-25th percentile) and the asterisk the mean.
Source: OECD Secretariat calculations.