The Impact of R&D Tax Incentives on Country's Location Attractiveness and Firm's Innovation Activities

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The Impact of R&D Tax Incentives on Country's Location Attractiveness and Firm's Innovation Activities

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Mannheim, December 2021 *Daniela Steinbrenner*

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LIST OF SYMBOLS

A	net present value of tax allowances
CoC	cost of capital
CoC_{Digi}	unweighted average cost of capital over all three digital business models
$CoC_{Best\ Case\ Domestic}$	cost of capital of a domestic digital transformation considering the most favourable conditions
$CoC_{Best\ Case\ B2C}$	cost of capital of a subsidiary of a digital B2C business model considering the most favourable conditions
$CoC_{Best\ Case\ B2B}$	cost of capital of a subsidiary of a digital B2B business model considering the most favourable conditions
E	required fixed income after taxes and social security contributions
E^*	total remuneration (before taxes) of the employee
$E_{qualified}$	share of own, qualifying R&D expenditures
$E_{overall}$	total of R&D expenditures
$EATR$	effective average tax rate
$EATR_{Digi}$	unweighted average effective average tax rate over all three digital business models
$EATR_{Best\ Case\ Domestic}$	effective average tax rate of a domestic digital transformation considering the most favourable conditions
$EATR_{Best\ Case\ B2C}$	effective average tax rate of a subsidiary of a digital B2C business model considering the most favourable conditions
$EATR_{Best\ Case\ B2B}$	effective average tax rate of a subsidiary of a digital B2B business model considering the most favourable conditions
F	net present value of financing expenses
F^D	net present value of debt financing expenses
δ	economic depreciation

i	nominal interest rate
i_{NID}	notional interest rate
$I_{overall}$	total amount of IP related income
$I_{qualified}$	share of qualifying IP related income
p	pre-tax rate of return
$\tilde{p}$	cost of capital
π	inflation rate
φ_0	initial expense of an investment (t=0)
φ_{IP}	share of qualifying IP income
r	real interest rate
R^*	net present value before taxes
R	net present value after taxes
T	overall tax burden
τ	corporate income tax rate
τ_{IP}	corporate income tax rate under IP box regime
$\tau_{IP\ nexus}$	effective IP income tax rate under the nexus approach

List of Abbreviations

Art.	article
AT	Austria
ATT	average treatment effect of the treated
B	buildings
B2B	business-to-business
B2C	business-to-consumer
BDI	Federation of German Industries
BE	Belgium
BEPS	Base Erosion and Profit Shifting
BG	Bulgaria
BMWi	Federal Ministry for Economic Affairs and Energy
BR	Brazil
C	current expenses
CA	Canada
CDU	Christian Democratic Union of Germany
CEO	chief executive officer
Ch.	chapter
CH	Switzerland
CIT	corporate income tax
CN	China
CoC	cost of capital
CSU	Christian Social Union
CY	Cyprus

CZ	Czech Republic
CVAE	Cotisation sur la valeur ajoutée des enterprises (contribution on the added value)
DE	Germany
Df	degrees of freedom
DiD	difference-in-difference
DK	Denmark
EATR	effective average tax rate
EE	Estonia
EFI	Expert Commission on Research and Innovation
e.g.	exempli gratia (for example)
EMTR	effective marginal tax rate
ES	Spain
et al.	et alii (and others)
etc.	et cetera (and so forth)
EU	European Union
EUR	Euro
FAT	funnel asymmetry test
FDI	foreign direct investment
FI	Finland
FR	France
G20	Group of 20
GDP	gross domestic product

GMM	generalized method of moments
GR	Greece
HR	Croatia
HTNE	Chinese High and New-Technology Enterprise Program
HU	Hungary
i.e.	id est (that is)
IBFD	International Bureau of Fiscal Documentation
ICT	information and communication technologies
IE	Ireland
IN	India
IoT	internet of things
IP	intellectual property
IT	Italy
IV	instrumental variable
IRAP	Imposto regionale sulle attività prduttive (regional tax on productivity)
JP	Japan
log	logarithm
LT	Lithuania
LU	Luxembourg
LV	Latvia
M	machinery
Max	maximum

Min	minimum
MNE	multinational enterprise
MRA	meta regression analysis
MT	Malta
N	number of observations
NID	notional interest deduction
NL	Netherlands
No	number
NO	Norway
NPV	net present value
Obs.	observation
OECD	Organization for Economic Cooperation and Development
p.	page
PCC	partial correlation coefficient
PEESE	precision effect estimate with standard error
PET	precision effect test
PL	Poland
pp	percentage points
PT	Portugal
R&D	research and development
RDD	regression discontinuity design
RO	Romania
RU	Russia

SE	Sweden
SE_{PCC}	standard error of the partial correlation coefficient
Sec.	section
SL	Slovenia
SK	Slovakia
SME	small and medium-sized enterprises
SPD	Social Democratic Party of Germany
SV 17	Steuervorlage 17 (Swiss' new tax regulation 17)
t	t-ratio
TR	Turkey
UC	user cost
US	United States (of America)
UK	United Kingdom
USD	United States Dollar
VCI	German Chemical Industry Association
vs.	versus
WHT	withholding tax
WTO	World Trade Organization
ZEW	Center for European Economic Research

1. Preface

It is widely recognised that a constant flow of innovation is a prerequisite for economic growth, global competitiveness and prosperity. Especially in an increasingly digital economy, innovation and investment in new technologies through digital transformation are mutually dependent and thus form the basis for efficiency gains and rising productivity. However, creating new innovations is risky and the private sector may not undertake the optimal level of research and development (R&D) activities. The tax system directly affects the risk-return profile of R&D activities, thus influencing firms' innovation activities in many ways. As a result, many countries use tax incentives that are specifically designed to promote R&D activities.

However, another argument why governments use various tax incentives is tax competition. Besides various non-tax factors such as production costs or market potential, it is well known that taxation can play a central role in the location decision of multinational companies (e.g., Feld & Heckemeyer, 2011). In addition to a tendency towards low tax rates, there has also been a recent trend towards special tax regimes that attract certain forms of investment, e.g., IP box regimes. Especially against the background of recent developments in the field of corporate taxation and the discussion about harmful tax practices of multinational companies as well as the design of an efficient and fair tax system, the interdisciplinary field of taxation and specifically corporate innovation and digitalisation is receiving current attention (OECD, 2015b, 2016, 2020).

Understanding the behaviour of innovative firms in the global economy and their response to the various forms of tax incentives, i.e., differentials in tax rates, tax subsidies or specific tax provisions is important when debating on the design of a fair and efficient tax system. This dissertation contributes to this debate along the line of three central questions:

(1) How have international tax systems for corporate investment and investment in labour, innovation and digitalisation evolved over the last decade and what are important factors influencing this development?

(2) To what extent is tax competition and location attractiveness driven by R&D tax incentives? How strong is the impact of more stringent substance requirements on the tax location attractiveness of countries?

(3) How does the evolution of R&D tax incentives and their design features impact their overall effectiveness in incentivizing R&D activity?

This dissertation addresses these questions in self-contained chapters that are based on five individually written research papers. The research papers have been originally prepared as submissions for publication in academic journals and include studies commissioned by PwC (PricewaterhouseCoopers), the European Commission and BAK Economics. Thereby, the papers are the work of multiple authors. Table 1 lists the papers included in this dissertation, depicts their current publication status, acknowledges the different co-authors and highlights my key contributions.

Chapter 2 is based on the paper “Tax policies in a transition to a knowledge-based economy – The effective tax burden of companies and highly skilled labour”, co-authored with Leonie Fischer, Jost Heckemeyer and Christoph Spengel. The second chapter addresses the first central questions of this dissertation. Globalisation and the fast-approaching digitalisation increase capital as well as labour mobility fostering tax competition among countries worldwide. Based on a unique dataset, my co-authors and I analyse the development of effective tax burdens on corporations and highly skilled labour for 26 OECD countries over the last decade. The synthesis of both indicators allows us to identify tax strategies of the countries considered and to further elaborate on the scope of future tax competition against the background of current developments. Overall, we find a declining trend in effective tax burdens on corporate investments, whereas we observe increases in the top statutory tax rates for high-income earners and a rather constant average effective tax burden on labour for a disposable income of EUR 100’000. Current developments like the agreement on a global minimum tax or the transition to a knowledge-based economy can set a new lower bound to tax competition on corporate investments and might shift its focus.

Chapter 3 is based on the study “Steuerlicher Digitalisierungsindex 2018: Steuerliche Standortattraktivität digitaler Geschäftsmodelle” conducted in cooperation with PwC, co-authored with Christoph Spengel, Katharina Nicolay, Marcel Olbert, Ann-Catherin Werner, Frank Schmidt and Thomas Wolf. In this third chapter my co-authors and I analyse the tax attractiveness of locations for investment in digital business models across 33 countries. Our analysis especially focuses on the application of such incentive schemes to activities carried out and investment assets employed in the digital economy. Our analysis shows that investments in digital business models face generally lower effective tax burdens than investment in traditional business models. The reasons therefore are twofold: First, investments in digital business models are characterized by a higher share of directly expensed investment costs. Second, a higher share of the core activities falls within the scope of existing R&D tax incentives for R&D input and/ or output. Our study thus provides new and objective insights in the evaluation of tax-related location factors and documents an increasing trend in tax competition for digital businesses.

Chapter 4 is based on the paper "R&D tax incentive regimes – A comparison and evaluation of current country practices", co-authored with Christoph Spengel and Barbara Stage. This fourth chapter addresses the second central question of this dissertation. The study in chapter 4 evaluates qualitatively and quantitatively the current R&D tax incentive regimes in place in ten important FDI countries (Belgium, Germany, Spain, France, Ireland, Netherlands, United Kingdom, Switzerland, China and the United States) considering effects on location attractiveness, innovative activity and profit shifting. The environment of offered R&D tax incentives has been highly dynamic in very recent years. Furthermore, the importance of innovative activities is accentuated during economic crisis. First, my co-authors and I qualitatively analyse the different design features of the existing R&D tax incentives in our sample countries. Second, we use forward-looking effective average tax rates to measure quantitatively their effect on location attractiveness. Our main finding is that input and output oriented R&D tax incentives continue to play an important role internationally and that the regimes in place have a considerable impact on forward-looking effective average tax rates, i.e. on countries tax attractiveness for R&D investments.

Chapter 5 is based on the paper "Does nexus pay off? Implications of the modified nexus approach on effective tax burdens and tax planning strategies of multinational enterprises", co-authored with Jessica Müller and Christoph Spengel. The fifth chapter addresses the third-central question of this dissertation. In this study, my co-authors and I examine in qualitative and quantitative terms European IP boxes and their impact on IP tax planning and location attractiveness in light of the changes introduced by the OECD's modified nexus approach. Our results demonstrate that a large reduction in the effective average tax burden is possible even after the introduction of the nexus. Nonetheless, in line with the policy intention to prevent BEPS, it effectively prevents excessive reductions of MNEs' tax burden. Accounting for changes in IP tax planning due to stricter substance requirements, combinations of out- and input-oriented tax incentives can be seen as attractive measures to reduce MNEs' tax liabilities and thus, increase the location attractiveness, as we observe implicit subsides, i.e., negative EATRs in 10 out of 16 states.

Chapter 6 is based on the paper "How does the evolution of R&D tax incentives schemes impact their effectiveness? Evidence from a meta-analysis.", co-authored with Florence Blandinières. This chapter addresses the last central question of my dissertation. The sixth chapter employs a meta-analysis to explain the heterogeneity found in the R&D tax incentive evaluations by the features of tax incentives. My co-author and I document that on average R&D tax incentives stimulate R&D expenditures across two streams of empirical studies. However, this averaged effect is moderated by the underpinning features of tax incentives. Our samples evidence that the estimations linked to incremental bases and related to targeted rules towards SMEs drive the positive results found in the literature. Introducing a cap or a pre-approval process does not decrease the effectiveness of R&D tax incentives, allowing governments to monitor the indirect support needed to stimulate private R&D expenditures. Our results highlight the importance of setting up a clear and stable tax incentives framework. Sources of uncertainty regarding the timespan, the amount of the financial returns from tax claims but also the main criteria to apply are likely to decrease their effectiveness in the short run.

Chapter 7 finally closes with a summary of the key findings of this dissertation.

Table 1: Own key contribution

Ch.	Project	Co-authors	Publication status	Own key contribution
2	Tax policies in a transition to a knowledge-based economy – The effective tax burden of companies and highly skilled labour	Leonie Fischer, Jost Heckemeyer, Christoph Spengel	Published as ZEW Discussion Paper No. 21-096. Submitted to *Intertax*	• Introduction and positioning of the paper • Qualitative literature survey on the impact of personal income taxation on labour migration • Research and implementation of relevant tax parameters using the Human Resource Tax Analyzer to calculate effective tax rates for the transition countries (2009-2013) and all countries (2017-2019) • Research and implementation of relevant tax parameters using the Devereux-Griffith methodology for the transition economies (2009-2019) • Evaluation and description of the results on labour taxation, syntheses and on the challenges of the current tax system and implication for policymakers
3	Steuerlicher Digitalisierungs-index 2018: Steuerliche Standortattraktivität digitaler Geschäftsmodelle	Katharina Nicolay, Marcel Olbert, Frank Schmidt, Christoph Spengel, Ann-Catherin Werner, Thomas Wolf	Published by PwC	• Collection, description and implementation of R&D tax incentives in the main analysis • Focus topic on the sensitivity of the results to R&D tax incentives with the research and implementation of the relevant tax parameters with discussion of results

Table 1: Own key contribution (continued)

Ch.	Project	Co-authors	Publication status	Own key contribution
4	R&D tax incentive regimes – A comparison and evaluation of current country practices	Barbara Stage, Christoph Spengel	Revise and resubmit *World Tax Journal*	• Introduction and positioning of the paper • Collection and description of information on IP box regimes and R&D tax incentives • Implementation and quantitative analysis of tax parameters in the calculation of effective tax rates • Qualitative literature survey
5	Does nexus pay off? Implications of the modified nexus approach on effective tax burdens and tax planning strategies of multinational enterprises	Jessica Müller, Christoph Spengel	Accepted for publication by *World Tax Journal*	• Introduction and positioning of the paper • Collection and description of information on IP box regimes and R&D tax incentives in EU member states • Conceptualization and implementation of the IP box regime rules into the model framework of the Devereux-Griffith methodology • Evaluation and description of the baseline results, sensitivity analysis for the nexus ratio, the debt-scenario as well as the combination with input-oriented R&D tax incentives • Summary of results
6	How does the evolution of R&D tax incentives schemes impact their effectiveness? Evidence from a meta-analysis	Florence Blandinières	Published as ZEW Discussion Paper No. 21-020. Revise and resubmit *Industry and Innovation*	• Elaboration and description of the institutional background and framework of R&D tax incentives • Collection of relevant studies • Development of coding guidelines • Coding of the variables of interest • Description of the data, estimation approach • Discussion of results on the structural approach and implementation for policymakers

2. Tax Policies in a Transition to a Knowledge Based Economy – The Effective Tax Burden of Companies and Highly Skilled Labour[1]

2.1. Introduction

Globalisation has reduced trade barriers and increased capital mobility. Hence, corporations decide in a globally integrated market where to locate their capital investments. Besides several non-tax factors like production costs or market potential, it is well established that taxation can play a pivotal role in the location decision of multinational enterprises (MNE). Since governments can most visibly influence the impact of taxation on this decision, countries worldwide participated in the "race to the bottom", continuously lowering statutory corporate income tax rates over the last decades. However, the agreement on a global minimum taxation can set a new lower bound to this race.

At the same time, due to the ongoing transition to a knowledge-based economy and the fast-approaching digitalisation, the transmission of ideas and meanings through labour mobility are increasing. This transition not only leads to an enhanced shift of economic activity from the manufacturing to the service sector, but also changes the characteristics of the labour force. In particular, the shift towards globally operating service sectors and an increasing demand for internationally mobile, highly educated employees are intensifying the competition for these actors (Hope & Limberg, forthcoming). The rising digital transformation of corporations and working conditions, such as remote working, further exacerbates this process (de la Feria & Maffini, 2021). Thus, increasing mobility and intensifying international competition for highly skilled employees may enable them to shift higher parts of non-wage labour costs – at least to some extend – to the employing MNEs. Consequently, the latter are not only confronted with the direct costs of corporate taxation but also with the economic consequences of the shifted incidence of labour taxation. Hence, the synthesis of corporate and labour taxation will be increasingly important for location decisions of corporations in the near future and thus, for the location attractiveness of countries.

[1] This chapter is joint work with Leonie Fischer, Jost Heckemeyer and Christoph Spengel. It is published as ZEW Discussion Paper 21-096. We gratefully acknowledge support from the MannheimTaxation Science Campus, funded by the Leibniz Association, the state of Baden-Württemberg, and the participating institutions ZEW and University of Mannheim.

So far, studies analysing the developments in tax competition set the focus only on one of both indicators – either corporate or labour taxation.[2] Our paper contributes to this literature and sheds further light to ongoing discussions by evaluating both levels of taxation. First, we provide a comprehensive, cross-country analysis of the evolution of tax location attractiveness in terms of corporate and labour taxation over the past decade (2009-2019). Second, the synthesis of both indicators contributes to a deeper understanding of the current challenges policymakers face in creating an optimal tax environment for business investments and the strategies chosen to address the transition to a knowledge-based economy.[3] Looking at effective tax rates over time provides us with an intuition about tax competition, especially within the EU, as well as common trends and possible interdependences between countries' national tax systems. More precisely, we present estimates on the effective tax burden on corporate investments and highly skilled labour for 26 OECD member countries. Specifically, we cover 18 Member States of the European Union (EU), Japan, Norway, Switzerland, and the United States (US), along with four key transition economies, namely Brazil, China, India, and Russia.

To analyse the development of the tax burden on corporations and labour, we rely on well-established effective tax measures, as they go beyond the statutory tax rate and are directly comparable due to their aggregated level in relation to different locations. Our estimates on the effective tax burden on corporations are based on Devereux and Griffith's (1999, 2003) methodology, whereas for the effective tax burden on highly skilled labour, we use the intertemporal simulation model developed by Elschner and Schwager (2005).

We still find wide dispersion in effective tax levels both on corporate and labour investments across countries. These large differences over time and region have the potential to significantly affect the geographical allocation of (innovative) businesses and highly skilled labour, especially in an integrated region like the European Union. Hence, it is increasingly important that governments pay attention to mobility responses when designing tax policy. Against the background on current developments, such as corporate minimum taxes and the transition to a knowledge-based economy, labour taxes might be an even more powerful instrument to increase a countries' location attractiveness from a tax perspective.

[2] For an exception, see Elschner et al. (2006). They provide a combined analysis of both aspects of taxation and find a strong correlation between both indicators for the majority of the countries considered for the early 2000s, i.e., 2003.

[3] For the synthesis of the two indicators, we mainly rely on the estimates of effective tax rates that we produce annually at the firm level for the European Commission (see Spengel et al., 2021), as well as on estimates of the effective employee tax burden in the context of the BAK Taxation Index (see BAK Economics et al., 2020).

The remainder of this paper proceeds as follows: In chapter 2.2, we present the empirical evidence on the impact of taxation on corporate location decisions and the mobility of highly skilled employees. In chapter 2.3, we give a brief overview of the methodology used to measure the effective tax burden before discussing the main results of the evolution of national tax burdens over the last decade. Estimates on company taxation and the taxation of highly skilled employees are first presented separately before considering them together in a synthesis. In chapter 2.4, we discuss our findings in the context of current tax policy developments and challenges. Chapter 2.5 concludes.

2.2. Influences of taxation on location decisions and the role of tax competition

2.2.1. Literature on the impact of corporate taxation

Over the last decades, increasing globalisation reduced trade barriers and fostered economic integration worldwide. Thus, several corporations are no longer operating in country-specific local markets but rather in a global marketplace. Against this background, numerous companies have significantly enhanced their international activities (Barrios et al., 2012; Schanz et al., 2017). In this context, they also have to decide how to serve the foreign market – either by establishing a foreign affiliate or exporting goods from their home country (Lawless et al., 2018). Several factors can determine the decision to set up an affiliated company abroad: On the one hand, non-tax reasons such as lower factor prices, market potential and access, or the size of the host market may be taken into account in the location decision of multinational firms.[4] On the other hand, corporate taxation can impact this decision. Due to non-harmonized tax regulations, firms can benefit from differences in the corporate tax systems across countries and governments can directly influence this factor to improve their location attractiveness for foreign direct investments (FDI). For governments, this is particularly relevant since several empirical studies confirm that FDI is linked to organisational expertise and new technologies that can increase productivity at an aggregated level in the host country (for a discussion of the literature see, Schiffbauer et al., 2017). Furthermore, FDI and, in particular, greenfield investments are associated with net job creation. Hence, to enhance its' productivity and competitiveness, governments around the world try to attract FDI using corporate taxation to improve their location attractiveness from a tax perspective (Davies et al., 2018).

[44] For the theoretical perspective, see Helpman (1984, 1985) for the vertical model or Markusen (1984, 2002) for the horizontal model. For reviews on the determinants of the location choice of foreign affiliates, see Fontagné and Mayer (2005), Lawless et al. (2014) or Davies et al. (2018).

Economists have long explored how tax policy impacts investment (R. E. Hall & Jorgenson, 1967; Cummins et al., 1995; Goolsbee, 1998; House & Shapiro, 2008). A vast theoretical public finance literature shows the sensitivity of capital location in general and in particular of multinational firms to profit tax policy (see, for example J. D. Wilson, 1987; Janeba, 1995; or Devereux & Hubbard, 2003). An extensive empirical literature has confirmed this result. Using data on different levels of aggregation (aggregated bilateral activity, industry, firm), these studies show that national tax policy on corporate profit taxation impacts the location decision of MNEs' investments across countries. One strand of literature relies on data of bilateral FDI flows (for an overview of earlier work, see Slemrod, 1990). For example, Devereux and Freeman (1995) analysed the effect of the effective marginal tax rate on bilateral FDI flows between seven countries and can confirm the impact of their measure in explaining the size of FDI flows relative to GDP. Several more recent papers rely their studies also on bilateral FDI flow data but exploring alternative specifications of the tax rate, e.g., effective average and marginal tax rate and forward-looking versus backward-looking measures (e.g., Buettner, 2002; Gorter & Parikh, 2003; Bénassy-Quéré et al., 2005). Considering the effective average tax rate as a linear combination of the (forward-looking) effective marginal and the statutory tax rate, Buettner (2002) finds that both measures significantly impact FDI flows. However, due to the aggregation level, the relevance of FDI flows with regard to the investment location decision of MNEs is limited.

Therefore, the second strand of literature uses aggregated data on affiliates of MNEs, including their activities in foreign countries. Several studies focus on the US, like Grubert and Mutti (1991, 2000) and Hines and Rice (1994). Concerning the results, for example, Grubert and Mutti (1991) and Hines and Rice (1994) show that the average tax rate negatively influences the aggregated capital stock of affiliated companies. However, to explore the differences in location decisions of MNEs more precisely and to study differences between corporations' data on firm-level is necessary. This strength of literature has been rapidly growing over the last two decades (for example, Devereux & Griffith, 1998; Stöwhase, 2002; Altshuler & Grubert, 2002; Desai et al., 2004; Schanz et al., 2017; Lawless et al., 2018). For example, Stöwhase (2002) uses a dataset on German MNEs analysing the number of affiliates of German MNEs in eight host countries. The results show that the average tax rate has a significant impact on companies in production industries, while the statutory tax rate plays a relevant role for companies in the service, finance, and R&D industries. More recently, Schanz et al. (2017) confirm – using not only corporate tax rates but several other tax variables – that German MNEs locate their affiliates in countries that offer favourable statutory tax rates, withholding taxes, double tax treaty networks and holding incentives. It is clear from this accumulated evidence that taxation does play a role in affecting the location choice made by multinational companies. However, tax is not equally important in all decisions. For example, effective average tax rates tend to play a significant role in discrete location choices, hence in the overall allocation of capital; but effective marginal tax rates are much less important (Devereux & Maffini, 2007).

Due to the extensive empirical literature studying the impact of taxation on the location decision of corporations, meta-studies shed further light on this question (de Mooij & Ederveen, 2003; Feld & Heckemeyer, 2011). For example, Feld and Heckemeyer (2011) estimate a semi-elasticity with respect to the corporate tax rate of 2.49, indicating that a one percentage point increase in the corporate tax rate of one country decreases its' FDI by 2.49%. Hence, besides several non-tax factors which are not included in our analysis, it is widely established that corporate taxation influences the location decision of corporate investments.

2.2.2. Literature on the impact of taxation on highly skilled labour

In contrast to the previous chapter, there is very little empirical work on the effect of taxation on the spatial mobility of individuals.[5] However, it is essential to consider income taxation not only as a potential distortion for corporate investments but also for the market of highly skilled human resources. Besides anecdotal evidence of the negative impact of taxation on top earners[6], there is growing evidence that taxes can affect the migration of employees both within and across countries, especially among high-skilled employees. These prior studies have shown that labour taxes can be used to attract highly skilled individuals and can also exert an effect on the wage-setting process of top earners.

With respect to attracting highly skilled labour, the small but growing literature on within and cross-border country migration shows that especially highly skilled employees and top earners significantly react to tax differentials through mobility across regions. Liebig et al. (2007) and Schmidheiny and Slotwinski (2018) find evidence for this subgroup of employees on within-country migration by exploiting discontinuities in Swiss cantons' income tax rates. Recent

[5] In the context of our analysis, we do not focus on the impact of taxation on other kinds of personal income, i.e. capital or business income, which comprises a majority of the income of superrich people. For more details on the impact of taxation on this type of top income earner, see Scheuer and Slemrod (2020).

[6] Some anecdotal evidence on the French wealth tax (a marginal tax rate of 75% for incomes above EUR 1 million) indicates that this tax was abandoned in 2015 not only due to its low incidence but also due to difficulties of French companies to attract top international staff, see Hopkins (2014, December 23; https://www.dailymail.co.uk/news/article-2885197/France-waves-discreet-goodbye-75-percent-super-tax.html).

analyses confirm this pattern of within-country variations for other countries (e.g., D. R. Agrawal & Foremny, 2019 for Spain; Rubolino, 2020 for Italy). Furthermore, these studies commonly stress that specific segments of the population (e.g., highly skilled employees, young and/or unmarried individuals (without family) and CEOs) are more sensitive to taxes, either because they are less tied to specific firms or their skills are less likely to be location-specific. Besides population characteristics, Agrawal and Foremny (2019) highlight the relevance of particular industries, i.e., scientific, health, finance, real estate and information industries, in driving the largest effects of migration. Concentrating on an even more specific subgroup of top earners, i.e., highly paid star scientists, Moretti and Wilson (2017) confirm the findings of interstate mobility within the US. In contrast, Young and Varner (2011) and Young et al. (2016) find only very limited effects of tax differentials at the US federal income tax level on millionaires' migration.

In the context of cross-border migration, the existing literature is even more focused on the impact of taxation on specific occupations, i.e., football players (Kleven et al., 2013), highly paid foreigners (Kleven et al., 2014) and inventors (Akcigit et al., 2016). These studies show that tax-induced migration of (foreign) top income earners can be important for local governments, especially in a large mobility area like the European Union (Muñoz, 2019). Participation in beggar-thy-neighbour strategies allows countries to take advantage of top earner's tax-driven mobility. Kleven et al. (2013) provided the first evidence on the positive (upper bound) effect of foreigner-specific tax breaks on immigration by analysing the European football market.[7] Based on panel data from the US and European Patent Offices, Akcigit et al. (2016) can track inventors over time and across countries and exploit the differential impact of top rates on inventors at different productivity and, therefore, income levels. The authors confirm the results of Moretti and Wilson (2017) in an international setting. Further evidence in this regard is provided by Akcigit et al. (2018) by showing a strong impact of corporate and personal taxes on the mobility of foreign inventors across US states over the twentieth century. Exploiting a preferential flat tax rate granted in Denmark for a maximum of 36 months after the immigration of highly skilled foreign employees, Kleven et al. (2014) do not only find a significant increase of highly paid foreigners eligible to this preferential tax scheme (i.e., the scheme almost doubled the number of highly paid foreigners in Denmark relative to slightly less paid ineligible foreigners), but they also provide evidence of wage bargaining power of these top earners. Even if they find evidence on a larger group of top earners, the migration

[7] Usually, football players can make their clubs pay the full cost of the tax thanks to their unique contracts, see Guillot (2021).

effects are quite heterogeneous between sectors, i.e., sports and entertainment, and all other industries (Kleven et al., 2020). Muñoz (2019) shows that countries included in a large mobility area like the European Union have increasing interests to participate in beggar-thy-neighbour strategies to take advantage of top earner's tax-driven mobility.

Besides the suggestive evidence on tax-induced migration effects within and across certain regions, our analysis rests on the assumption that highly skilled employees exert enough bargaining power to shift at least part of their labour tax burden to the employer. Recent literature on the incidence of labour taxes finds very different results, ranging from full incidence among employers (Saez et al., 2012) to full incidence among employees (Gruber, 1997). However, in line with Ruf and Schmider (2018), Kleven et al. (2014) point out in the context of highly skilled employees and CEOs that they seem to be able to shift part of their payroll tax burden to employers. Guillot (2021) confirms these findings by analysing the impact of the French 75% tax on millionaires. However, she stresses that the bargaining power, and thus, the incidence is highly driven by the employees' occupation, both upon the introduction and the removal of the tax. Especially, CEOs and, to a lesser extent, admin and business managers exert a higher share of bargaining power. Engineers and technical managers bear half of the incidence and do not benefit as much as the others from the removal of the wealth tax.

Based on the empirical evidence presented, any increase in the taxation of highly skilled employees could result in a (partly) offsetting increase in the remuneration and thus increase companies' labour costs. As multinationals are especially quite sensitive to costs, higher employer-borne taxes and social security contributions could exert negative investment distortions. Feld and Kirchgässner (2002), who exploit the regional distribution of companies and on cantonal employment using a panel data set of the 26 Swiss cantons from 1985 to 1997, show that corporate and personal income taxes deter companies from locating in a canton and subsequently reducing cantonal employment. Additional evidence of the sensitivity of firms to variation in top labour income tax rates is provided by Egger and Radulescu (2011) and Egger et al. (2013) in their studies, where they show that firms tend to locate their headquarters where top tax rates and tax progression are lower. In detail, Egger et al. (2013) find that a one percentage point increase in the payroll taxes (i.e., personal income taxes and social security contributions) reduces the probability of a country attracting headquarters by 6.1%. Further indirect empirical evidence on the negative impact of labour costs is provided by Buettner and Ruf (2007), Buettner and Wamser (2009) as well as Montout and Sami (2016). Implicitly controlling for labour taxes by including labour costs in their analyses, these studies find a significant negative effect of labour taxes on cross-border location and investment decisions.

Overall, there is evidence that first, highly skilled employees react to tax incentives through within and cross-border country migration. Second, the literature has shown that these employees use their bargaining power to shift – at least some parts – of their labour tax burden to the employer.

2.3. Trends in effective tax burdens of corporations and highly skilled labour

To identify trends in a countries' location attractiveness from a tax perspective for corporations and highly skilled employees over the last decade, we rely on well-established measures of the effective tax burden at the corporate level as well as on labour, namely the models developed by Devereux and Griffith (1999, 2003) and Elschner and Schwager (2005).[8] These effective tax rates should be preferred over statutory tax rates as they incorporate the most significant features of the underlying corporate and personal income tax system, e.g., tax allowances, local profit tax rates, surcharges, non-income tax charges as well as social security contributions, and could therefore point out distortions of taxes on investment decisions.

To analyse the attractiveness of different locations from a tax perspective, we compare effective tax burdens on corporations and labour internationally. In particular, we compare 18 EU Member States and four major industrialised non-EU countries (i.e., CH, JP, NO, and the US) and four transition economies (i.e., BR, CN, IN, and RU). In the majority of countries, corporate and personal income tax rates are only set at the federal level. However, we also cover certain countries which levy income taxes on the national and sub-national levels (e.g., BE, CH, DK, ES, FI, IT, JP, NO, SE, and the US). Further, regional differences in social security contributions drive variations in the Chinese tax burden. In the context of our analysis, we, therefore, focus on the regulation applicable in the capital cities if there are local differences within a country.[9]

2.3.1. Development of effective tax burden on corporations

2.3.1.1 The Devereux-Griffith methodology

The Devereux-Griffith methodology (2003) builds on the work of Jorgenson (1963), Hall and Jorgensen (1967) and King and Fullerton (1984) and is based on the neoclassical investment theory. It assumes a perfect capital market under certainty and considers a hypothetical domestic incremental investment by a corporation in the manufacturing sector. This investment

[8] Our focus on the taxation of corporations and highly skilled employees is not meant to imply that we deny the importance of other location factors such as infrastructure or environmental amenities. Rather, we concentrate on taxation so as to clearly isolate the impact of one specific location factor.

[9] In CH we refer to the canton and city of Zurich and in the US to the state of California.

takes place in one period and generates a return in the subsequent period. Further, it assumes that firms undertake the hypothetical domestic investment as long as its' marginal return covers its' marginal costs. Said differently, investment takes place until the return is equal to the cost of capital – the minimum pre-tax real rate of return required by an investor given a post-tax real rate of return on an alternative (financial) investment.

The methodology of Devereux and Griffith allows us to compute effective tax burdens on marginal investments that just yield a minimum required return (relevant measure: cost of capital, effective marginal tax rate (EMTR)) and on highly profitable investments with a pre-tax rate of return of 20% (relevant measure: effective average tax rate (EATR)). For this study, we only consider the EATR at the corporate level with the aim to analyse the impact of taxes on the location attractiveness of countries for corporate investments over time.[10]

The EATR measures the change in the net present value (NPV) of a highly profitable investment caused by taxation. This is especially relevant when companies have to decide on the geographical allocation of economic returns in the course of investment location decisions(Devereux and Griffith, 2003; Auerbach, 2006). From a set of discrete, mutually exclusive investments with an identical pre-tax real rate of return, the investor will choose the location for which the NPV is least reduced by taxation, that is, the EATR is lowest.[11]

The EATR is computed as the difference of NPV before and after taxes ($R^* - R$), divided by the discounted pre-tax rate of return p.

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

Alternatively, the EATR can be written as:[12]

$$EATR = \frac{\tilde{p}}{p} * EMTR + \frac{p - \tilde{p}}{p} * \tau \tag{2}$$

Hence, the EATR equals the EMTR if the pre-tax rate of return (p) is identical to the cost of capital ($\tilde{p}$). Further, the EATR approaches the statutory tax rate τ if profits increase (i.e., an increasing pre-tax rate of return). Therefore, the corporate income tax rate can be considered the main driver of the EATR for highly profitable investments, whereas tax base elements considerably decrease for such investments (Devereux and Griffith, 2003; Spengel, 2003).

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[10] It is adequate to disregard taxes at the shareholder level in case managers do not know the tax position of their marginal shareholder. For a discussion of these issues, see Devereux et al. (2002).

[11] For an illustrative example and interpretation, see Spengel et al. (2018).

[12] Personal taxes are neglected. For the derivation, see Devereux and Griffith (1999).

To calculate the effective average tax burden, the model considers country-specific information on the type of the tax system, applicable profit and non-profit taxes (e.g., corporate income tax, real estate tax, etc.), as well as tax base and tax rate regulations.[13] Besides these country-specific tax information, the model rests on several important economic assumptions displayed in Table 2. All economic parameters are held constant across all investments to isolate the effect of different international tax regimes, irrespective of their location.

Table 2: Parameters of Devereux-Griffith methodology

Economic parameters	
True economic depreciation rate (%)	
intangibles	15.35
industrial building	3.1
machinery	17.5
real interest rate (%)	5
inflation rate (%)	2
pre-tax rate of return for EATR (%)	20
Composition of investment	
Weighting of investment (%)	
Intangibles, buildings, machinery, inventory, financial assets	each 20
Weighting of financing (%)	
Retained earnings	55
New equity	10
Debt	35

Source: Assumptions based on Spengel et al. (2021).

2.3.1.2 Tax burden on profitable investment projects – country comparison 2009-2019

Statutory corporate income tax rates

All countries considered in our sample apply a flat statutory rate to tax corporate profits. In addition, some countries like Germany, Italy, or India levy additional surcharges or business taxes that increase the statutory corporate income tax rate. Therefore, the combined corporate income tax rate (statutory tax rate incl. surcharges/business taxes) can deviate from the statutory rate. Before evaluating the trends of effective average tax rates over the last decade, we focus on the development and distribution of statutory as well as combined profit tax rates, as these are often used as a first indicator of the effective tax burden on corporate investments.

[13] For further details, we refer to the annual update on effective tax level in the EU; see Spengel et al. (2021).

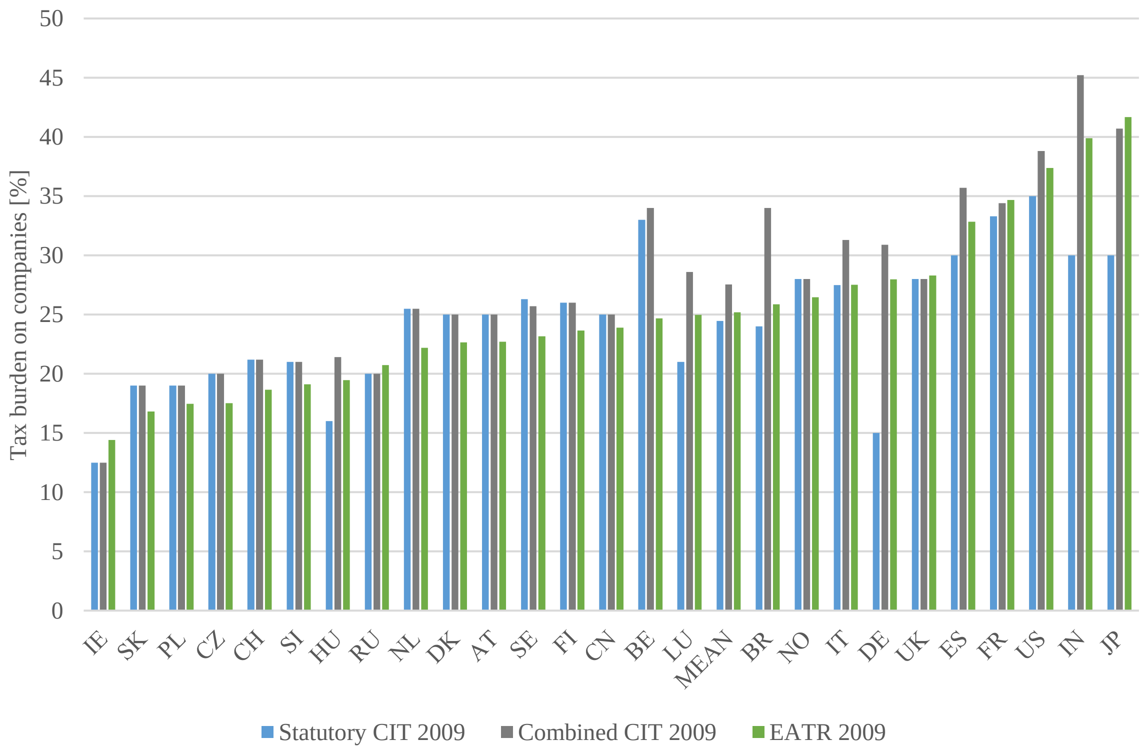
Figure 1 and Figure 2 graphically illustrate the statutory, combined and effective average tax rates for all considered countries for the years 2009 and 2019 (see also Appendix 1). A glance at the timeline of the different averages shows a significant trend downwards across all tax rate measures. Overall, average statutory corporate income tax rates (combined tax rates) decreased from 24.5% (27.5%) in 2009 to 21.6% (24.7%) ten years later. The modest reduction in the standard deviation of statutory tax rates (combined tax rates) indicates that the difference in national tax levels persists over the observation period (5.7 (7.5) in 2009 to 5.0 (7.3) in 2019).

Within our sample, the average combined profit tax rate on distributed profits is 24.7%, and the remarkable spread between the highest and the lowest profit tax rate amounts to 35.2 percentage points (pp) in 2019. In this regard, Hungary and Ireland levy the lowest combined corporate income tax rate at 11.1% and 12.5%, respectively, and India the highest at 46.3%. In India, companies face an above-average statutory corporate income tax rate of 30%, further increased by an additional dividend distribution tax (15%), surcharge and educational tax levy.[14] In comparison, the average combined corporate income tax rate in the EU is 23%.

The dispersion of statutory and combined profit tax rates indicates significant regional variation, partly reflecting the underlying tax systems. Most large economies complement corporate income taxes by surcharges and local business taxes (e.g., DE, FR, ES, IT) or state taxes (e.g., CH, US). In contrast, the majority of Eastern European countries considered, as well as Russia, not only apply slightly below average corporate income tax rates but also use relatively simple tax regimes without any additional surcharges on profit, revenue or other business assets.

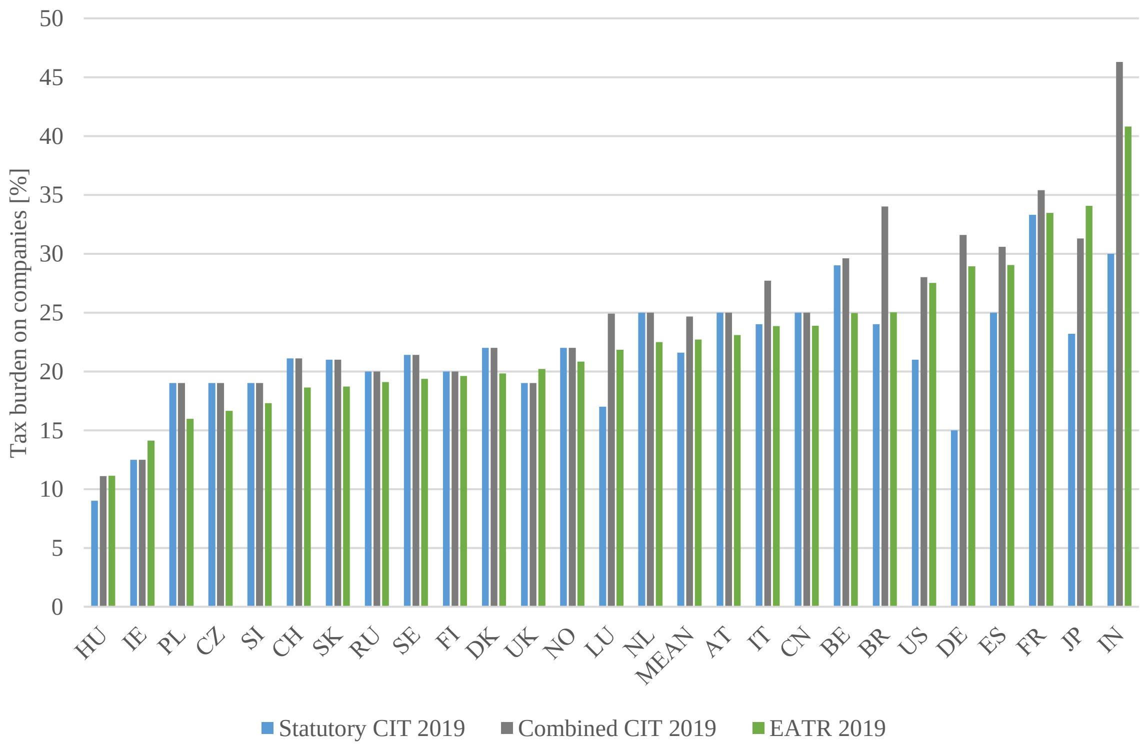
[14] The effective tax burden of an Indian company is determined by the product of the sum of the corporate income tax rate and the distribution tax and the surcharge as well as educational tax levy ((30%+15%)*1.12*1.04).

Figure 1: Statutory, combined and effective average tax rates for corporations in 2009



Source: own illustration based on Spengel et al. (2021), own calculation and illustration for transition economies.

Figure 2: Statutory, combined and effective average tax rates for corporations in 2019



Source: own illustration based on Spengel et al. (2021), own calculation and illustration for transition economies

Effective average tax rates

Concerning effective average tax rates, the figures mentioned above show that in the majority of countries, the EATR is lower than the combined statutory tax rate due to the tax-reducing impact of tax base regulations and the deduction of interest payments on debt financing.

Appendix 2 presents the respective EATRs for 26 countries every two years, starting from 2009 to 2019. In line with the developments of statutory and combined corporate income tax rates, the results show, on average, a decline in EATRs (25.2% in 2009 vs. 22.7% in 2019) as well as a remarkable dispersion across countries that persist over the observation period. In 2009, the EATRs ranged from 14.4% in Ireland to 41.7% in Japan, while in 2019, Hungary shows the lowest EATR with 11.1% and India the highest with 40.8%. However, these trends might differ between regions, especially between EU- and non-EU countries.

Although the average level of effective tax burdens is slightly lower compared to the overall sample, the above-mentioned trends – on average – can also be observed for the EU Member States considered with a decreasing unweighted average EATR of 23.3% in 2009 and 21.1% in 2019. Furthermore, the nearly constant standard deviation suggests that a comparatively high cross-country spread in EATRs persists over time (5.3 in 2009 vs. 5.4 in 2019). The slightly lower level of EATRs compared to the overall sample is mainly driven by the tax burdens of the five Eastern European countries, namely the Czech Republic, Hungary, Poland, Slovakia, and Slovenia. Compared to the other Member States considered, the unweighted average EATR of the Eastern European countries is around seven percentage points lower, at 18.1% in 2009 and 16.0% in 2019. With a standard deviation of 1.0, the levels of effective tax burdens for corporate taxpayers in these five countries were very much aligned in 2009. However, due to contrary developments in Hungary and Slovakia, the spread in EATRs across these Eastern European countries increased significantly and resulted in a standard deviation of 2.6 in 2019.

As these findings already imply, the location attractiveness from a tax perspective differs significantly within the European Union. Already in 2009, France, Spain, and Germany showed the highest EATRs among the EU Member States considered with 34.7%, 32.8%, and 28.0%, respectively, and are still the top three high-tax countries in 2019. Whereas the German effective tax burden increased slightly due to, on average, increasing local scaling factors of the business tax and the lack of major tax reform, the EATRs in France and Spain decreased to 33.5% and 29.0% in 2019. Especially, a rather strong EATR decline of 3.8 percentage points can be observed in Spain, which is due to several cuts in the statutory corporate income tax rate (2009: 30%, 2015: 28%, 2016: 25%). From a tax perspective, the most attractive investment condition was offered by Ireland in 2009 with an EATR of 14.4%. While Ireland's effective corporate tax burden has been relatively constant over the observation period (2019: 14.1%), Hungary significantly reduced the statutory corporate income tax rate by ten percentage points from 16% to 9% with major tax reform in 2017. As a result, Hungarian corporations faced the lowest average effective tax burden in 2019 among the European countries under consideration.

Besides the most noticeable EATR reduction in Hungary (-8.4 pp), the effective average tax burden for corporations in the UK has fallen by 8.1 percentage points from 28.3% in 2009 to 20.2% in 2019. This substantial decline is also due to continuous reductions in the statutory corporate tax rate (from 28% in 2009 to 19% from 2017 onwards).[15] Another seven out of the 18 EU Member States considered showing a decline in EATRs of slightly above or around three percentage points. Most of these countries reduced their statutory corporate income tax rate (e.g., FI, SE, LU, ES), while Italy introduced a notional interest deduction in 2011, leading to a lower corporate income tax base. In contrast to the strong decreases in EATRs among the Member States considered, only Austria, Belgium, Germany, and the Netherlands faced slight increases in the effective tax burdens of their corporate taxpayers, ranging from 0.3 percentage points (BE) to 0.9 percentage points (DE). These increases are mainly caused by local profit as well as real estate taxes. By contrast, the increases in the effective tax burden of Belgian corporations until 2017 are due to significant reductions in the eligible rate for the notional interest deduction (around 4.5% in 2009 to 0.2% in 2017). Hence, it broadened the corporate tax base and therefore increased the EATR. This increase was not fully offset by the Belgian tax reform in 2018, which reduced the statutory corporate income tax rate from 33% to 29%. The most substantial increase of 1.9 percentage points between 2009 and 2019 in effective average tax burdens among the European Member States considered can be observed in Slovakia. This country significantly increased its corporate income tax rate by four percentage points in 2013. Taken together, the Northern and Eastern European countries considered show a stronger trend towards declining effective average tax burdens on corporate investment in comparison to Central and Western European Member States.

The four industrialised non- EU countries – Japan, Norway, Switzerland, and the US – show on average a significantly higher level of EATRs compared to the 18 EU Member States during the last decade. Nevertheless, a declining trend of EATRs can also be observed in these countries: The average EATR of 31.0% in 2009 decreased to 25.3% in 2019. While in

[15] The planned decrease of the corporate income tax rate to 16% in 2020 was abolished due to the Covid-19 pandemic.

Switzerland, EATRs stayed almost constant over the observation period, EATR reductions in Japan, Norway, and the US drive the aforementioned EATR decline.

Due to the "Tax Cuts and Jobs Act" of 2017, the US – besides introducing several other tax law changes – reduced the federal statutory corporate income tax rate from 35% to 21% as of 2018. Compared to all other countries considered, this reform is the main driver for the most substantial decrease in EATRs – namely 9.9 percentage points – over the entire observation period.

Between 2009 and 2019, Japan also steadily reduced the statutory corporate income tax rate, with a major decrease of 4.5 percentage points from 30% to 25.5% in 2012. From 2014 onwards, the statutory tax rate was even further decreased; however, the respective steps were rather small (2015: 23.9%, 2016: 23.4%, 2018: 23.2%). The observed declines in EATRs over the last decade have led to a 7.6 percentage points reduction of the EATR in Japan and thus to the most vital improvement of location attractiveness from a tax perspective after the US (-9.9 pp.), Hungary (-8.4 pp.), and the UK (-8.1 pp.). In line with the observations in Japan and the US, the declining trend in EATRs can also be observed in Norway. Similarly, it is mainly driven by reductions in the statutory corporate income tax rate. However, in contrast to the other two countries, there has not been one major reduction but rather several continuous steps with similar magnitudes. While the statutory corporate tax rate amounted to 28% for the years 2009 to 2013, Norway started to reduce it by one percentage point in (nearly) each subsequent year, resulting in a statutory corporate tax rate of 22% in 2019.[16] Besides the aforementioned cuts in the statutory tax rates, other temporary tax law changes could counteract (e.g., special reconstruction tax in JP from 2012-2015) or even amplify the effect (e.g., accelerated depreciation for machinery and equipment in NO from 2014-2016).

Overall, the significant decrease of the effective corporate tax rate in Japan led to an alignment with the European high-tax countries. Whereas corporate taxpayers in Japan faced a nearly seven percentage points higher tax burden than their counterparts in France in 2009 (41.7% vs. 34.7%), this difference in effective tax levels narrowed down to 0.6 percentage points ten years later. Hence, Japan is – from a tax perspective – equally attractive for corporate investments as France in 2019. Similar improvements in location attractiveness can be observed for the US. While in 2009, the tax burden for corporations in the US was higher than in every other EU Member State under consideration, this has changed significantly due to their major tax reform

[16] The statutory corporate tax rates for the years 2014 to 2019 are the following: 2014-2015: 27%, 2016: 25%, 2017: 24%, 2018: 23% and 22% in 2019.

in 2017 and no or rather moderate reforms in the EU high-tax countries France, Spain, and Germany. Hence, in 2019 the situation is reversed – with EATRs of 33.5%, 29.0% and 28.9%, taxpayers in France, Spain, and Germany faced higher tax burdens than US corporations with an effective average tax rate of 27.5%. Finally, with an almost constant EATR of around 18.6% over the last decade, Switzerland provides rather attractive investment conditions compared to the considered EU Member States. Lower EATRs can only be observed in the European low-tax countries, namely the five Eastern Member States and Ireland.

In contrast to the aforementioned observations, the overall trend of declining EATRs over the last decade cannot be perceived for the four key transition economies Brazil, China, India, and Russia. While the effective corporate tax burdens in Brazil, China, and India stayed (almost) constant over the last decade, only a minor EATR decrease from 20.7% to 19.1% can be observed in Russia. Since the statutory corporate income tax rate is unchanged over the observation period, the EATR reduction is due to an exemption of fixed assets from the corporate property tax as of 2013. Compared to the overall sample, India offered the least attractive investment conditions in 2019 due to the absence of tax reforms during the last decade. The EATR of 40.8% in 2019 is far above the tax burden of every other high-tax country in the sample. The effective corporate tax burdens in Brazil and China are slightly above average compared to the Central and Western European Member States considered, while Russia's EATR is comparable with the one of the Northern EU Member States Sweden, Finland and Denmark.

Overall, we show that, on average, there is a declining trend in EATRs over the last decade as well as a remarkable dispersion of EATRs across countries that persist over the observation period. As shown above, these developments depend on the national tax reforms of the countries under consideration. In general, the level of the effective corporate tax burden depends on the statutory corporate tax rate, tax base regulations, and the imposition of additional income and non-income taxes on corporations by the respective country. Hence, a comparison of the statutory corporate income tax rate with the corresponding EATR allows a conclusion on changes in the tax base as well as on other corporate taxes considered in the model (Endres et al., 2013). It is evident that the EATR correlates strongly with the statutory corporate tax rate of the respective country. Hence, a high statutory tax rate is associated with a high EATR. This traces back to the assumption of a highly profitable investment. As profits increase, i.e., an increasing pre-tax rate of return, the EATR approaches the statutory tax rate, which becomes the decisive factor with regard to the corporate tax burden. Consequently, higher profits are associated with a declining impact of tax base elements, e.g., depreciation allowances, relative to the absolute value of the profits (Bärsch et al., 2014; Spengel & Olbert, 2016). Therefore, in the vast majority of the considered countries, the EATR is not significantly lower than the statutory and combined tax rate. This holds for the years 2009 and 2019.

In ten out of the 26 OECD countries, the combined corporate income tax rate exceeds the statutory tax rate in 2009 and 2019.[17] This traces back to additional (local) business taxes levied in these countries, which can account for up to 50% of the combined corporate income tax rate, such as in Germany. Further, some local business taxes take the form of taxes on gross profits without a deduction allowance for financing and/or labour costs. Such taxes are levied, for example, in Hungary (iparu zési adó), Italy (IRAP), and France (CVAE)[18]. In contrast to the vast majority of the countries considered, the effective average tax rate is higher than the statutory and combined tax rate in France, Ireland, Japan, Russia, and the UK in 2009. The reasons behind it are in general twofold: First, in Japan, Russia, and the UK, the depreciation regulations according to the countries' tax law are less favourable than the economic depreciation assumed in the model for some assets considered. For example, in the UK in 2009, industrial buildings could be depreciated over 50 years under the straight-line method resulting in an annual depreciation rate of 2%. However, the underlying economic depreciation rate assumed in the model is significantly higher at 3.1%. Thus, these national tax regulations of the respective countries increase the net present value after taxes and lead to a higher EATR. Second, France, Japan, and Russia levied a wealth tax in general or only with regard to specific assets considered in the model in 2009. This tax increased the effective tax burden of the corporation but is neither considered in the statutory nor in the combined corporate income tax rate. However, Russia and France abolished this tax or excluded the considered assets from the tax base during the observation period. Therefore, the EATR was lower or equal to the statutory and combined tax rate in 2019.

Regarding Ireland, the explanation differs: Trading income is taxed at a statutory tax rate of 12.5%, whereas non-trading income, such as interest income, is taxed at a much higher rate of 25%. Since the model also considers an investment in financial assets, we adjust for this issue resulting in a higher effective average tax burden for corporations compared to the statutory and combined income tax rate on trading income.

[17] The combined corporate income tax rate exceeds the statutory tax rate in BE, BR, DE, HU, IN, IT, JP, LU, ES and the US in 2009 and 2019.

[18] The tax on the added value of business was introduced in 2010 under the name of cotisation sur la valeur ajoutée des enterprises.

Overall, in line with previous studies, we find a declining trend in statutory as well as effective corporate tax burdens in the EU. However, comparing our results to previous work (see, for example, (Bräutigam et al., 2019), we observe that the downward trend of effective average tax burden slowed down in the last decade.

2.3.2. Development of effective tax burden on highly skilled labour

2.3.2.1 The Human Resource Tax Analyzer model

To analyse the effective tax burden on highly skilled labour, we rely on the effective tax measure developed by Elschner and Schwager (2005), the so-called Human Resource Tax Analyzer.[19] This approach rests on the assumption that highly skilled employees are perfectly mobile across countries, which allows them to demand a specific disposable income after taxes when choosing among job offers. Based on the empirical evidence summarized in chapter 2.2.2, we assume that especially highly skilled employees in a competitive labour market can shift their respective burden of labour taxes and tax-like social security contributions to the employer. Thus, differences in these country-specific non-wage labour costs lead to distortions in the cost of labour of a highly skilled employee. In particular, employers are required to compensate their employees for these higher charges on labour income to stay competitive in an international comparison. Said differently, the higher the perceived labour costs of companies due to taxes and social security contributions payable by the employer, the less attractive is a country for companies employing highly skilled employees there.

To measure and analyse the differences in national regulations concerning labour costs, the methodology by Elschner und Schwager (2005) allows us to calculate the effective average tax burden for a fixed disposable income after taxes and social security contributions. The EATR represents the tax wedge, reflecting the share of the remuneration which does not benefit the highly skilled employee. Thus, the EATR expresses how much the employer has to expend in addition to the predetermined disposable income due to taxation. This is especially relevant when companies have to decide on the geographical location of highly skilled employees. High effective average tax rates indicate that the employer has to spend significantly more to compensate an internationally mobile employee. Or, to express it in the context of our study,

[19] For a detailed explanation of the methodology, see Elschner and Schwager (2005), Elschner and Schwager (2007). The Human Resource Tax Analyzer is closest to the OECD publication series on „taxing wages“. However, there are two significant deviations: First, this approach suggests that social security contributions should not treated as a whole as tax-like contributions. Second, it takes into account the tax impacts on old-age contribution (Elschner & Schwager, 2005).

the higher the EATR, the less attractive is a country for companies employing highly skilled employees.

The EATR is computed as the difference between the total remuneration of the employee (pre-tax value (E^*)) and the required fixed income after taxes and social security contributions (after-tax value (E)) divided by the total remuneration (pre-tax value (E^*)).

$$EATR = \frac{E^* - E}{E^*} \tag{3}$$

In line with the Devereux-Griffith methodology, which we use to calculate effective corporate tax burdens, the Human Resource Tax Analyzer incorporates information about current and future tax payments and charges that occur in the context of the total remuneration in one period. In detail, we consider all personal income taxes, including surcharges, state and municipality taxes. On the company's side, we take into account payroll taxes applicable to the aggregate wage costs. Furthermore, we consider social security contributions as part of the tax burden as long as it can be assumed that employees do not earn a specific individual benefit by participating in these schemes. Hence, we explicitly treat the contributions to unemployment insurance and accident insurance as tax-like contributions. On the other hand, due to the unavailability of the precise tax component in healthcare premiums, we do not treat these contributions as taxes (Elschner et al., 2006). Concerning mandatory public pension schemes, we carefully account for the benefits provided by such schemes according to the regulations currently in force in each country. Following Elschner and Schwager (2007), we take account of the fact that payments into a public pension scheme can at least partially be considered as insurance premiums even if the benefits provided are typically not actuarially fair.

Different types of compensation determine the total remuneration of employees. We restrict our analysis to cash compensations (75%) and contributions to old-age provisions (25%). Cash compensations are taxable in the year of payment, whereas the treatment of old-age provisions is not straightforward. If the contributions are paid out of taxed income, the resulting benefits are non-taxable, whereas the initial exclusion of the old-age contributions from taxable income results in taxable old-age benefits. The intertemporal approach of Elschner and Schwager (2005) explicitly deals with the different timing of income payments and their consequences on taxes and social security contributions by considering personal characteristics of the highly qualified employee like contribution years and life expectancy (see Table 3).

We express our disposable income for all locations in Euro to obtain internationally comparable effective tax rates. Thus, we have to convert the disposable income into the national currency of a country unless the local currency is Euro. To isolate fiscal changes and abstain from fluctuations in currency exchange rates, we use fixed nominal exchange rates, displayed in Appendix 5.[20]

Table 3: Parameters of Human Resource Tax Analyzer

Personal characteristics of highly qualified employee	
Current age	40 years
Age at start of work	25 years
Age at retirement	65 years
Life expectancy	85 years
Status	Single, without children
Economic parameter	
Real interest rate (%)	5
Disposable income (baseline)	EUR 100'000
Composition of remuneration	
Cash components (%)	75
Old age contributions (%)	25

Source: Assumptions based on Elschner and Schwager (2005), BAK Economics et al. (2020).

2.3.2.2 Tax burden on highly qualified employees – country comparison 2009-2019

Statutory personal income tax rates

Although average effective tax rates should be the decisive factor for location choices, statutory top personal income tax rates are often of high relevance for individuals and thus, can have an important signalling effect for many employees. Consequently, it is very likely that these tax rates could have an impact on international labour tax competition (de la Feria & Maffini, 2021). Therefore, we first provide a brief overview of the evolution of statutory top personal income tax rates over the last decade.

In contrast to corporate taxation, most of the countries considered rely on a progressive tax schedule for labour income. Within our observation period, only a few countries, i.e., the Czech Republic, Hungary, Slovakia, and Russia, use a flat statutory tax rate – at least temporarily. In this case, the tax burden is mainly driven by the statutory tax rate of the respective country. In contrast, if a country applies a progressive tax schedule, the tax burden depends not only on the statutory tax rate but also on the size and distribution of the income brackets. Within the group

[20] Further, we do not adjust our assumed disposable income to inflation. If we converted with purchasing-power parities, to remain consistent, we would also have to convert the disposable income within the euro region. In any case, the effect of inflation adjustments on the country rankings are moderate.

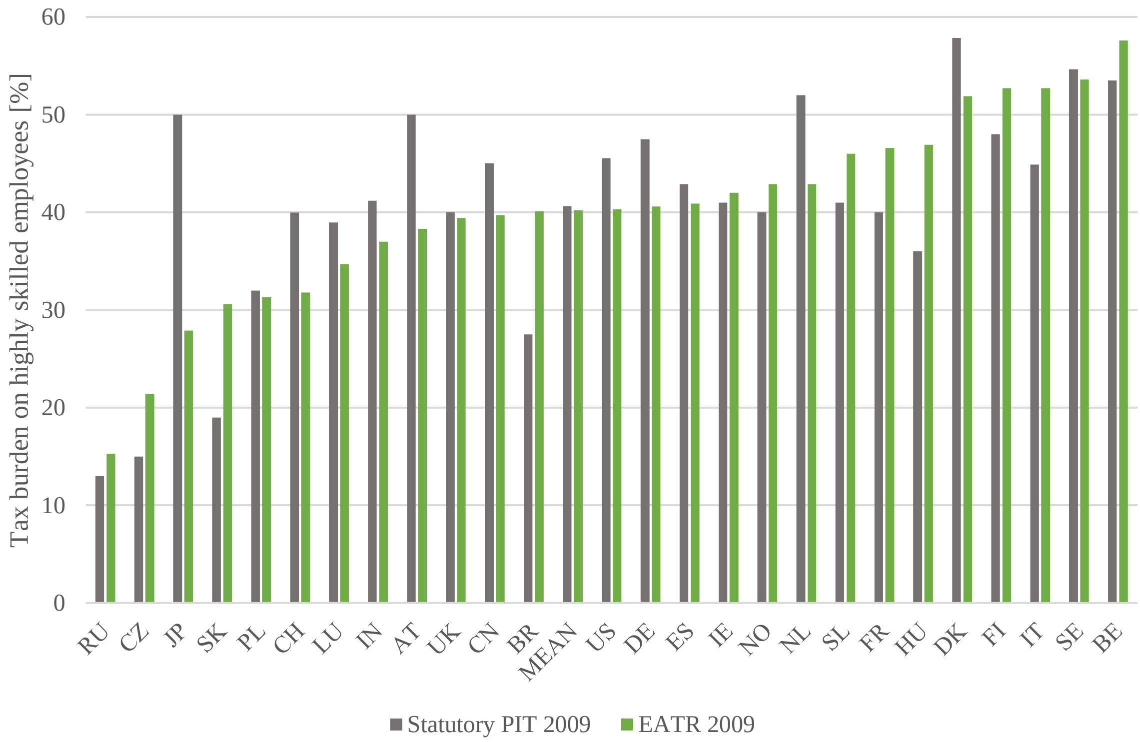
of countries levying progressive tax rates on labour income, a stepped progression tariff is used, except for Germany applying a linear progression schedule. Both progression types have an income-dependent increase in the average tax rate. However, while the linear progression increases steadily, the increase in the stepped progression has a ripple effect depending on the size of income brackets. The number of income brackets with a flat marginal tax rate is at least two (e.g., CZ, DK, IE, PL, SK) and can be subdivided indefinitely (e.g., LU with up to 23 brackets). With an increasing number of income brackets, it approaches the linear progression. Figure 3 and Figure 4 display the evolution of the top personal statutory income tax rates, including local surcharges over the last decade (see Appendix 3).[21]

In contrast to the declining trend in statutory corporate income tax rates, we observe a slight increase in the unweighted average top personal income tax rate from 40.6% (2009) to 42.1% (2019). In addition, the simultaneous increase in the standard deviation (11.5% in 2009 to 12.4% in 2019) shows a further divergence in statutory tax rates within our group of countries. In contrast, the overall spread of personal statutory income tax rates stagnated over the last decade resulting in a constant, substantial dispersion. In this regard, Russia levies the lowest personal income tax rate at 13% and Belgium and Denmark the highest at 58% in 2009 and 2019. Still, significant differences in the level and development of top personal income tax rates can be observed between individual countries and regions.

Employees in the EU face an average statutory tax rate of 43.3%, which is slightly higher than the overall average in our country comparison. This results in above-average wage costs for hiring a highly qualified employee in this region. In addition, this region follows the general trend of slightly increasing income tax rates (41.9% in 2009 vs. 43.3% in 2019), except for Denmark, Hungary, and the Netherlands. Among these three countries, Hungarian employees experienced the most drastic personal income tax reform. In 2011, Hungary did not only reduce its top personal income tax rate by 20 percentage points but also abolished the progressive tax schedule. In doing so, Hungary followed the trend of other Eastern countries (i.e., CZ in 2008, SK in 2009).

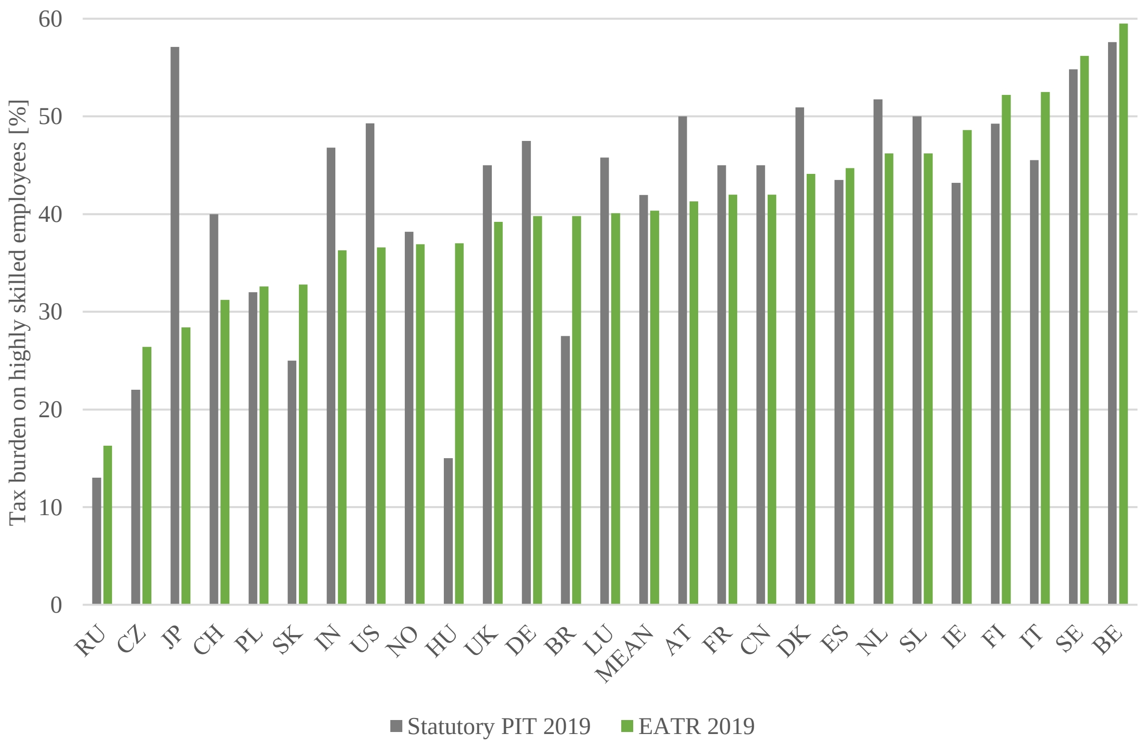
[21] Several countries levy taxes also at the regional level (i.e., BE, CH DK, FI, IT, JP, NO, SE, and the US), whereas a general surcharge is levied in seven countries (i.e., BE, CZ, DE, IE, LU, IN and JP). For more details on the respective income brackets, see Table 5 in appendix.

Figure 3: Statutory tax rates and effective tax burdens on highly skilled labour, 2009



Source: own illustration based on BAK Economics et al. (2020), own calculation and illustration for BR, IN, JP, RU for the year 2009.

Figure 4: Statutory tax rates and effective tax burdens on highly skilled labour, 2019



Source: own illustration based on BAK Economics et al. (2020).

In general, there are significant differences at the regional level within the EU. The Western Member States as well as the UK and Ireland, have comparatively high statutory top tax rates with an average of 48%. The Eastern Member States stand out in the comparison group with low to moderate top tax rates, ranging from below 25% in Hungary and the Czech Republic to 50% in Slovenia. In comparison, the four industrialised non-EU and the four transition economies show a stronger increase in personal income taxes. Although, this increase is strongly driven by increasing tax rates of individual countries, i.e., Japan (+7.1 pp), India (+5.2 pp) and the US (+3.8 pp). Whereas most of these countries face comparatively high tax rates of over 40%, Russia and Brazil have comparatively low statutory personal income tax rates.

In addition to the absolute level of the top statutory tax rates, however, the absence or length of the progression is also decisive for the effective tax burden. Within the countries considered, Austria, Germany, Switzerland, and the US stand out in particular, as the top personal income tax rate takes effect relatively late (e.g., DE: EUR 250’000, JP: EUR 271’089, CH: EUR 512’211, the US: EUR 608’259 and AT: EUR 1’000’000). In Austria, Switzerland, and the US in particular, the top marginal tax rate is more comparable to a wealth surcharge, as it only takes effect at a very late stage.

Effective average tax rates

In the second set of estimations, we present the EATRs for an employee, who is unmarried without children and demands a disposable income of EUR 100’000 after taxes and charges (see Appendix 4). In contrast to the evolution of the average statutory top personal income tax rate, we do not observe an overall increase in the average effective tax burden over the last decade (40.2% in 2009 vs. 40.3% in 2019). Still, our results show a wide dispersion of effective tax levels on highly skilled employees across countries, with a total spread of more than 40 percentage points in both periods. In 2009, the EATRs range from 15.3% in Russia to 57.6% in Belgium, while in 2019, the lowest EATR in Russia slightly increased to 16.3%, whereas the highest EATR decreased to 59.5% for Belgium. To better illustrate these differences, we translate the EATRs back into total remuneration costs an employer faces in each location.[22] Thus in 2019, employers incurred expenses of EUR 119’474 in Russia to compensate their highly skilled employees for a disposable income of EUR 100’000 after taxes. In contrast, Belgium employers had to pay with EUR 246’914, more than twice the amount, to grant the same disposable income.

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[22] To obtain the total amount of remuneration, transformation of equation (3) gives us the following formula: $E^* = E/(1 - EATR)$, with the disposable income $E = 100'000$.

Among the countries considered, the EU Member States show, on average, an above-average level of the effective tax burden as well as an increase in the unweighted average EATR of 42.8% in 2009 to 43.4% in 2019. This higher level of effective tax burdens is driven by the Continental EU Member States, including Ireland and the UK, as their average tax burden is with 45.7% in 2009 and 46.6% in 2019 significantly higher than the overall average. Except for Germany and the UK, all Northern and Continental European countries, including Ireland, show effective tax rates above the unweighted average of 40.3% in 2019. With a tax burden of less than 40%, the two largest EU economies in terms of GDP, i.e., Germany and the UK, are in good company with other major industrialised non-EU countries, such as the US, and can also compete with emerging economies like India and Brazil. Whereas other large EU countries like Italy and France, even catching up since its major pension system reform in 2019[23] (-4.6 pp), lag behind. Luxembourg had a rather moderate effective tax burden of labour at 34.7% in 2009 but approached the overall average EATR with 40.1% in 2019. With Ireland, another rather small EU economy showed one of the most significant increases in the effective tax burden (+6.6 pp) over the last ten years, which is due to several cuts in personal tax credits, allowances as well as the abolition of the employee's income ceiling to global social insurance.

Not surprisingly, we find that the Scandinavian countries levied relatively high tax levels – topped, however, by Belgium. Already in 2009, Belgium, Denmark, Finland, Italy, and Sweden raised the highest EATRs among the EU Member States considered with more than 50%, and are still the top high-tax countries in 2019, except for Denmark. Among these high-tax countries, a relatively strong EATR decrease of 7.8 percentage points to 44.1% can be observed in Denmark in 2019 due to several reductions in the top statutory tax rate as well as adjustments in the progression schedule and personal allowances.

In comparison, Eastern European countries face significantly lower effective tax burdens than their Western counterparts, averaging 11 percentage points. Slovenia is the only Eastern European country with a tax burden of over 40% and is, therefore, surrounded by high-tax countries. Further, this region showed an opposite trend with even a slight reduction over the last decade, at 35.2% in 2009 and 35% in 2019. However, this decrease is driven by the big tax reform in Hungary in 2011, which led to a decline of the Hungarian EATR by 9.9 percentage points. The Hungarian reduction in EATR overcompensated the observed increases in EATRs

[23] The reform of the occupational pension system (integration of the two previously existing constructs into one system, which is shown to be advantageous in the modelling, especially for high incomes) results in a significant reduction of the effective burden which is accompanied by a slight reduction of the effective tax burden due to adjustments of the progression schedule of the personal income tax. For more information on the French pension tax reform in 2019, see https://www.cleiss.fr/docs/regimes/regime_france/an_3.html.

in the other Eastern Member States, e.g., the introduction of a solidarity surcharge in the Czech Republic in 2013 (+5 pp). Especially, the countervailing reforms in the Czech Republic and Hungary, which had the lowest and highest tax burdens in the Eastern countries considered in 2009, have led to a significant convergence of the effective tax burden in this region.

In 2019, the four industrialised non-EU countries, i.e., Japan, Norway, Switzerland, and the US, levied low to moderate effective tax burdens on labour, ranging from 28.4% in Japan to 36.9% in NO. Thus, these countries showed, on average, a significantly lower level and slightly decreasing EATRs compared to the EU counterparts during the last decade: The average EATR decreased from 35.7% in 2009 to 33.3% in 2019. While we observe a slight EATR reduction in Switzerland, Japan faced a minor increase. The most interesting developments in this group of countries can be observed in Norway and the US, with rather large declines of 6 and 3.7 percentage points over the last decade. In both countries, the reduction is attributable to extensive reforms in 2018 and 2019, which not only adjusted income tax rates and brackets but also significantly increased various personal allowances and deductions for income-related expenses. In line with the other non-EU countries, the four key transition economies raised a moderate effective labour tax burden between 2009 and 2019, with a relatively constant average tax burden of around 33%. However, the range among these countries is much broader, from 16.3% in Russia to 42% in China in 2019.

The main tax drivers of the effective tax burden are, on the one hand, the statutory personal income tax rate, including its progressive evolution, and, on the other hand, social security rates (if classified as charges)[24] in combination with income ceilings. Still, the composition of the effective tax rate, i.e., the split between taxes and contributions of the total effective average tax rate, varies across countries. In some countries, e.g., in Hungary, contributions to social security outweigh the personal income tax. In other countries, e.g., in Belgium, the personal income tax accounts for by far the largest share of the total effective average tax rate. The personal income tax base, i.e., personal allowances, earned income allowances, deductibility of social security contributions, and taxation of old-age benefits, are typical of secondary importance at these high-income levels.

The absolute minimum and maximum of the effective average tax burden, i.e., Russia and Belgium, reflect the extremes of the distribution based on the statutory top tax rate and show, therefore, the significant influence of the statutory tax rate on the effective average tax burden.

[24] We explicitly treat the contributions to unemployment insurance and accident insurance as charges.

Russia applies a flat income tax of only 13% with ceilings on old-age as well as unemployment social security contributions, whereas Belgian employees already face a top rate of 57.6% on income above EUR 40’480 without ceilings in social security. The EATR’s sensitivity to the development of the income tax rates is also reflected in Spain. Initially, we observe a continuous increase in the Spanish effective tax burden up to 47.5% in 2013, after which the EATR levelled off at a constant level of around 44%. The basis for this decline (-3.5 pp) was a comprehensive reform of personal income taxation in 2011.[25] Since then, regions can independently choose on additional tax brackets and rates. As we focus in our analysis on the capital Madrid, which is referred to as a Spanish tax haven for personal income taxation, we capture the significant reduction of Madrid’s regional top marginal tax rate.

Besides the top personal income tax, the progressive schedule is decisive for the effective average tax burden. Among other countries in our sample, Japan applies a long progression, which results in a lower effective tax burden. An applicable stepped progression further enhances this effect. For this reason, we observe the most substantial divergence between the statutory tax rate and the EATR in Japan. In our baseline scenario with a disposable income of EUR 100’000, the Japanese employee earns a taxable income of EUR 66’136, subject to a maximum tax rate of 35.1% on the excess of EUR 47’102.[26] Similarly, the long, stepped progression drives the divergence in Luxembourg, Germany, Switzerland, the UK, and the US.

The second main driver of the effective average tax burden is the social security system. In particular, the existence of income ceilings above which no further contributions are payable or their absence. If there are comparably low ceilings, only smaller fractions of the income are subject to social security contributions, reducing the implicit tax burden. Although most countries have a rule to limit social security contributions, the approaches are quite heterogeneous. Not only do the contribution limits differ in their absolute amount, but they can also be restricted to the employee or employer as well as to different types of social insurance. We only observe income ceilings for all branches of social security for both the employee and the employer in Austria, China, the Czech Republic, Germany, India, Luxembourg, the Netherlands, Slovakia, Spain, the UK, and the USA. A particular low ceiling of less than EUR

[25] Since 2011 personal income tax rates are not only set at the federal level but also on a regional level. In detail, regions are allowed to introduce new tax brackets on top of those implemented by the federal level. For more institutional details on this reform, see Agrawal and Foremny (2019).

[26] The Japanese employee faces a gross income of around EUR 111’113 which is for tax purposes further decreased by existing personal allowances as well as allowances on earned income. For a taxable income above EUR 47’102 (JPY 6’950’000) and below Japanese employees face a tax rate of 35.1% (=23%+2.1%+10%), which combines the personal income tax, reconstruction income tax and the residence tax.

3’500 exists in India, which drives the divergence of the EATR from the statutory tax rate. Further, we observe comparably low absolute amounts of social security contributions in Denmark, which positively impact the tax burden.

Another example that shows the importance of income thresholds on the effective average tax burden is the abolition of the proportional tax and the simultaneous increase of the top tax rates in the Czech Republic and Slovakia in 2013. The Czech Republic introduced a solidarity surcharge of 7% on top income earners (income above EUR 59’068), whereas Slovakia introduced a progressive tax system for individuals, increasing the top rate from 19% to 25% for taxable income above EUR 37’163. In both countries, the impact of the decreasing importance of social security contributions due to their ceilings outweighs the increase in personal income taxes. These developments show the importance of ceilings on social security contributions, especially for high-income earners. By contrast, the absence of a social security contribution ceiling in Hungary drives the stronger increase in the EATR compared to Russia. This effect is enhanced by higher combined contribution rates (e.g., more than 40% in HU vs. around 30% in RU[27]). Besides Belgium, Finland, Hungary, Ireland, Norway, and Slovenia do not apply any social security contribution ceiling. Thus the overall contribution rate is payable on all income.

In contrast to our results on corporate investment, we observe an increase in the top statutory tax rates for high-income earners, which in some countries resembles the intention of a wealth surcharges on the superrich, whereas the average effective tax burden on labour for a disposable income of EUR 100’000 remained relatively constant over the last decade.

2.3.3. Synthesis of effective average tax burdens of both indicators

To analyse the overall attractiveness of countries for investments from a tax perspective, we combine our indicators for the effective average tax burden of companies and highly qualified employees. Figure 5 and Figure 6 graphically illustrate the EATR at the corporate level together with the EATR of a single highly skilled employee with a disposable income of EUR 100’000 for the years 2009 and 2019. The y-axis reflects the effective average tax burden of a corporation, whereas the x-axis displays the effective average tax burden of highly qualified employees. In both cases, the (unweighted) average is represented by the grey line. Since the

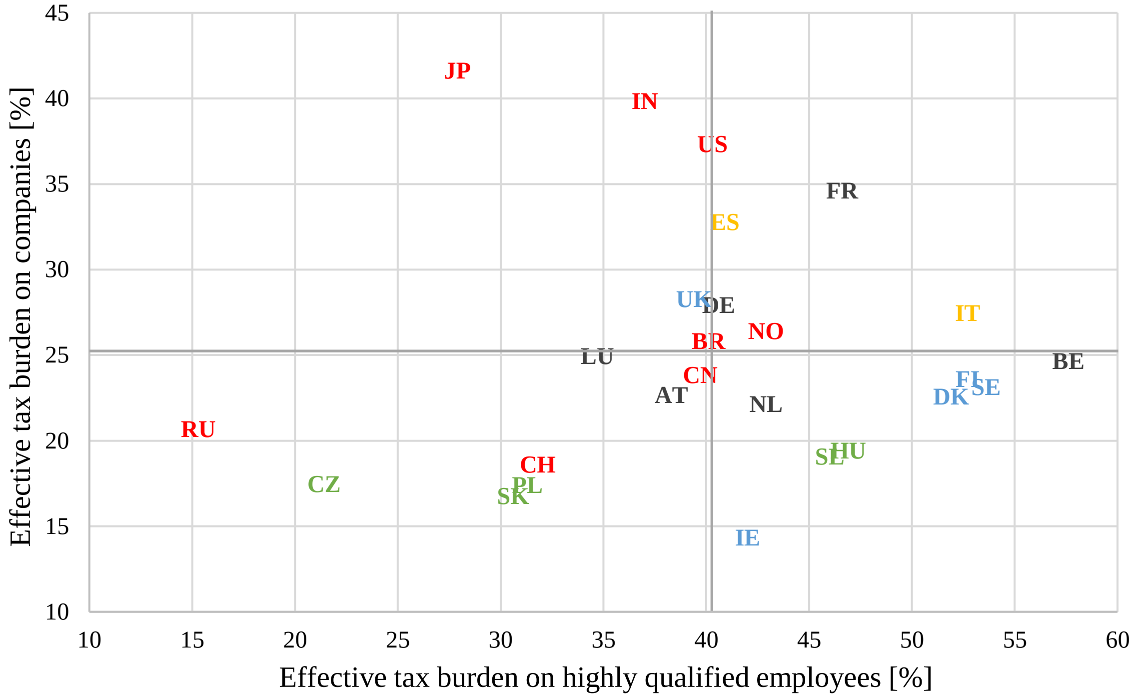
[27] RU applies an income ceiling to the old age insurance (EUR 16’313) and the unemployment insurance (EUR 12’270). Contributions to the health insurance as well as occupational accident insurance are not capped. In our model, especially contribution to the unemployment insurance represent charges in contrast to the health insurance, thus resulting in a higher increase in the effective tax burden. Further, in RU only the employer faces contributions to the social security system.

underlying methodologies to calculate the respective EATR slightly differ, we focus on the ranking and relative differences of both indicators for the respective countries in the following analysis.

At first glance, the significant reduction in the average EATR of corporations already discussed above is striking (2009: 25.2%; 2019: 22.7%), whereas the average EATR on employees stays almost constant over the observation period (2009: 40.2%; 2019: 40.3%). Furthermore, the synthesis brings forward that the effective tax burden levied on highly skilled labour may differ substantially from the effective tax burden imposed on companies. Comparing the two Figures in this regard shows that the overall picture for 2009 and 2019 is similar. However, some countries significantly moved their position – horizontally and/or vertically – resulting in a change in their location attractiveness for corporate investments and/or employing highly skilled employees. Hence, the synthesis leads us to the following conclusions for the countries under consideration:

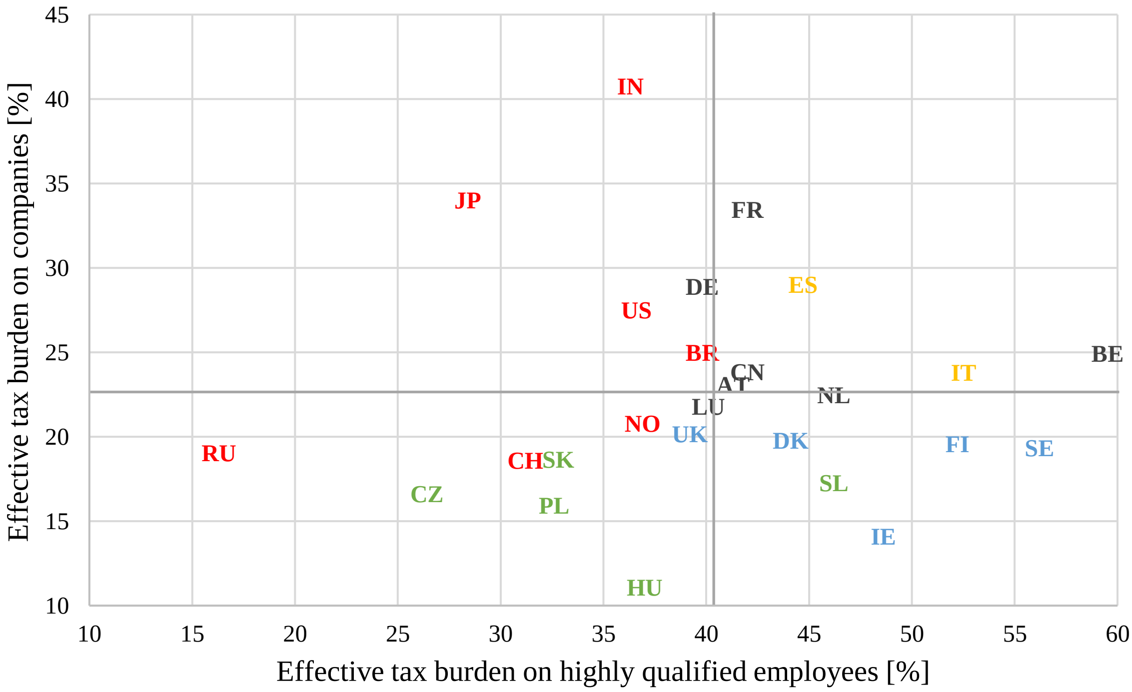
Central and Western EU Member States are characterised by moderate to high tax burdens on labour, with a trend towards above-average effective tax burdens in 2019. This development is accentuated as the average EATR on labour was nearly constant over the last decade for the countries analysed. Thus, in an international comparison, Central and Western EU countries lose ground in the tax competition on highly skilled labour. Among these countries, only Germany and France reduced their effective tax burden on highly skilled employees, while all other countries in this cluster increased. Throughout the observation period, Belgium offers the least attractive conditions for investments in highly qualified employees. With an effective average tax burden of close to 60%, Belgium lies nearly 20 percentage points above the overall average. For companies, on the other hand, the picture is more differentiated, but one that is typical of corporate tax competition. Large economies such as France and Germany impose high EATRs on corporations, while taxpayers in the smaller countries like Austria, Luxembourg or the Netherlands face rather average corporate tax burdens. As of 2019, only Luxembourg provides a below-average effective corporate tax burden compared to the countries analysed. Since the corporate EATRs remained nearly constant in the majority of these countries over the last decade, Central and Western EU countries also became less attractive for corporate investments from a tax perspective. In addition, the location attractiveness of these Member States and, especially for Germany and France, depends on the point of view: Germany and France, which are high-tax countries concerning company taxation, indicated moderate tax levels with regard to the taxation of highly skilled labour. Taken together, countries of this cluster levy moderate to high effective average tax rates on companies

Figure 5: Correlation of tax burdens on corporations and highly skilled employees, 2009



Source: own illustration

Figure 6: Correlation of tax burdens on corporations and highly skilled employees, 2019



Source: own illustration

as well as on highly qualified employees.[28]

Within the Northern EU countries, including Ireland and the UK, Scandinavian companies already faced a below-average effective corporate tax burden and Ireland offered the most attractive investment conditions at the beginning of the observation period. In contrast, the UK imposed one of the highest effective tax burdens within the EU in 2009. Due to significant tax reductions for companies in the Scandinavian countries, i.e., Denmark, Finland, and Sweden, as well as the UK, all countries of this cluster levy below-average EATRs on corporate investments in 2019. Concerning highly qualified employees, the evolution is more dispersed. Whereas Sweden and Ireland increased the effective tax burden on labour significantly, the UK further improved its competitiveness for highly skilled employees by offering minor reductions in the EATR. Denmark occupies a special position in this country cluster, as it drastically reduced its effective tax burden on highly qualified employees. Overall, this country cluster is characterised by below-average taxation of capital (companies) and a rather above-average taxation of labour (highly qualified employees). The most pronounced representative of this tax strategy is Ireland, which was the most attractive location from a corporate tax perspective while imposing moderate taxes on labour in 2009. Over the last decade, Ireland has maintained its attractiveness for corporate taxation but is now one of the five EU countries with the highest tax burden on highly skilled employees.

In our study, Southern EU Member States are represented by the two largest economies in this region, i.e., Italy and Spain. Both countries significantly reduced their effective average corporate tax burden over the last decade. While Italy remained nearly constant on the effective tax burden on labour, Spain compensated part of the decrease on capital taxation with increasing taxes on the more immobile factor labour. Nevertheless, throughout the observation period, both countries provide above-average effective tax rates on capital as well as on labour.

The group of Eastern EU Member States shows an ambivalent development in the last decade. In an international comparison, the considered Eastern EU countries remain the most fiscally competitive, at least when looking at corporate taxation. Except for Slovakia, all countries in this group show at least a slightly declining effective average corporate tax burden. Hungary, however, is an exception, having almost halved its effective corporate tax burden to just over 10%. In contrast to their reputation as low-tax countries for corporate taxation, there is no clear

[28] With regard to corporate EATRs, moderate tax burdens are imposed by AT, LU, and NL, whereas BE, DE, and FR levy high corporate tax burdens. Concerning highly skilled employees, AT, LU, FR, and DE tax them at a moderate level, while the tax burden in BE and NL is high compared to the overall sample.

trend among Eastern EU countries in the taxation of highly skilled employees. The declining corporate tax burden contrasts with a slight increase in effective labour taxation in the majority of the Eastern EU countries. Hungary also stands out here because it has significantly reduced its effective average tax burden on highly skilled labour, unlike all other countries in this cluster. Hungary has thus developed from a location with a rather moderate tax burden to a low-tax country for both indicators. Except Slovenia providing above-average taxation on labour, all other countries in this cluster are characterised by below-average taxation on capital as well as on labour.

Among the non-EU countries, a distinction must be made between several country clusters. Brazil, China, and Norway tax corporations and highly skilled labour on a moderate level close to the average effective tax burden of the comparison countries. In contrast, Russia and Switzerland follow a clear low-tax strategy for corporate as well as labour taxes. Finally, India, Japan, and the US differ remarkably from all other countries analysed. In 2009, the tax burden on companies was among the highest of all countries considered. Japan and the US significantly reduced the EATR on corporate taxpayers during the observation period but are still among the high-tax countries in 2019. In contrast, highly qualified labour is taxed quite moderately or even at a comparably low level. Thus, their strategy consists of very moderate taxation of highly skilled employees combined with a (rather) substantial tax on corporate income. Especially the latter group, i.e., Japan and the US, drives the trend of convergence of effective corporate tax burdens towards the average tax burden in 2019. India did not have substantial changes in the last decade and thus, occupies the last position for corporate investments over the whole observation period. In contrast to all other non-European countries, China slightly increased its overall tax burden on highly skilled employees, whereas it remained nearly constant or even slightly decreased in other non-EU countries. Over the entire observation period, Russia holds the top position with the lowest tax burden for highly skilled employees.

Overall, based on the EATRs for the majority of the countries considered, a clear pattern can be identified in terms of the tax strategies chosen for corporate investment and labour in 2019. Thus, the countries analysed can either pursue a strategy in which both indicators are taxed at a high or low tax rate (relative to the average) or in which a mix of these two strategies is chosen.

First, it is noticeable that the considered Eastern EU Member States – except for Slovenia – as well as Russia and Switzerland follow a classic low-tax strategy for both indicators. By contrast, representatives of the second strategy – namely Belgium, France, Italy, and Spain – impose above-average effective tax burdens on corporations and highly skilled labour. Therefore, these countries offer the least attractive conditions from a tax perspective for corporate investments and employing highly skilled employees, whereas countries belonging to the first group are the most attractive.

Besides these two strategies, we can clearly distinguish between two (regional) groups that pursue a mixture of both strategies by taxing one indicator above average and the other below average. The considered Northern EU Member States, as well as Ireland and Slovenia, are characterized by a below-average effective average tax burden on mobile capital income, whereas the less mobile factor labour, in our analysis highly qualified employees, face above-average EATRs. In the fourth strategy, the tax burden on both indicators is reversed: India, Japan and the US tax corporations above and highly-skilled employees below average. Thus, these countries offer attractive investment conditions for one indicator but are less attractive for the other.

Finally, over the last decade, we can perceive serval changes in countries' location attractiveness, which led in parts to a reallocation of countries between the four groups mentioned above. The reasons for it are twofold: On the one hand, some countries actively influenced their position via tax reforms (e.g., DK, HU, US). On the other hand, due to the tax competition of several considered countries, passive states that lack major tax reforms lost ground and got, in general, less attractive for investments in capital and labour (e.g., BR, DE).

2.4. Future developments and challenges

Against the background of current political developments and progressing digitalisation, it is unclear whether the "race to the bottom" with regard to statutory corporate tax rates will continue in the future. Immediately after the end of our observation period, hence in the years 2020 and 2021, we can still observe some countries improving their location attractiveness for corporate investments by reducing their statutory corporate income tax rate. For example, Belgium decreased its statutory tax rate from 29% to 25% in 2020. France, a high-tax European country, also showed improvements in its location attractiveness by gradually reducing its statutory tax rate from 33.3% in 2019 to 27.5% in 2021. Due to these reforms and a lack of action in Germany, France eliminated the EATR difference of 4.5 percentage points in 2019 between these two countries and became equally attractive from a tax perspective. However, not only middle to high-tax countries showed positive developments in this regard but also Switzerland that follows a classic low-tax strategy, improved its position even further (EATR 2019: 18.6%; 2020:17.4%).

Nevertheless, in the short run, the economic consequences of the Corona crisis that hit countries worldwide unexpectedly in 2020 might impact the further development of tax competition. In order to delay the spread of the virus, contact and exit restrictions have been issued, private and public events have been banned and business closings have been ordered (so-called lockdown). This led to both a drop in demand and supply, which were exacerbated by the disruption of international supply chains. As a result, corporations of several industries which were profitable before the crisis faced enormous revenue declines leading to a loss-making situation. Therefore, at least in the short run, the tax policy focus has changed. As a primary goal, governments worldwide have utilized tax policy instruments to ensure a firms' liquidity and enhance its cash flow. In the mid-term, measures like accelerated or enhanced depreciation schemes will be (temporarily) implemented aiming at the economic recovery by boosting corporate investments and consumption. It is evidently clear that tax, as well as non-tax measures, increased government spending drastically. Hence, in the long run, these additional expenditures have to be financed by fiscal consolidation measures. Therefore, as the crisis hit all economies worldwide, it seems less likely that the race to the bottom concerning statutory tax rates will continue in the near future. In contrast, we may even observe increases in statutory tax rates like already passed by the UK (increase in statutory tax rate from 19% to 23% until 2023). However, the current location attractiveness of a country might impact the discussion on whether to increase the tax burden on corporate investments. Finally, in a downturn of the economy, lowering statutory tax rates can counteract the introduced tax measures since it will decrease the tax shield of enhanced depreciation regimes and losses that can be offset against future profits.

Another current political development might curb the trends in tax competition on corporate investments that we have observed over the last decades, namely, a global minimum tax. As of 9 July 2021, over 130 member countries of the OECD/G20 Inclusive Framework on BEPS have agreed on a two-pillar solution to address the tax challenges arising from the digitalisation of the economy (OECD, 2021a). The second pillar constitutes the global minimum tax. Although several details on the exact design of the regulations are still unclear, the agreement includes the minimum tax level, with a rate of at least 15%. This minimum level sets the benchmark against which the effective corporate tax payable in a country is assessed, whereby the current blueprint focuses on a country-by-country analysis for multinational enterprises (OECD, 2020). The major argument on its introduction is based on the strong dispersion of effective corporate tax rates across countries (see subchapter 2.3.1.2) and empirical findings (see subchapter 2.2.1), demonstrating that firms do not necessarily choose investment locations according to productivity but according to tax differentials. As a sufficiently large number of countries has agreed to levy minimum taxes, low tax countries could be inclined to increase their national corporate tax rate up to the minimum tax rate in the future as this would not increase the firms' tax burden (since these corporations would pay the minimum tax rate anyway). A minimum tax reduces these tax differentials and, thus, lowers the distortion-induced efficiency losses, i.e., it sets a floor for tax competition clearly above 0%.

With regard to our estimates of the EATR, two of the countries considered are significantly below the 15% threshold (HU: 11.1%, IE: 14.1%), assuming that the corresponding tax base of the minimum tax would be in line with our model assumptions. Thus, for MNEs operating from or making payments to these countries, cross-border activities would increase the effective tax burden up to the determined minimum tax level. However, we have to treat these observations as a rough approximation as the impact of the minimum tax depends on several conditions: First, the final scope of the minimum tax, second, the exact design of the tax base, and third, the specific investment mix of an MNE, as this can significantly affect the effective tax burden.[29]

In addition, the tremendous pace of new digital innovation and digital transformation raises the relevance of an attractive tax environment for highly skilled labour. With an increasing international demand for highly qualified workers due to growing investments in digitalisation (Balsmeier & Woerter, 2019) and a limited labour supply, MNEs face an intensifying international competition. As a result, it is even more difficult to pass on the tax burden to employees and thus increases the employer's non-wage labour costs. A (comparatively) high taxation of labour income can therefore not only lead to new jobs tending to be created in low-tax countries but also to the relocation of existing jobs abroad (Niemann & Schreiber, 2020). The increasing digitalisation of business models and working conditions, i.e. remote working, amplifies this trend of international flexibility of highly skilled labour demand. In particular, services that can also be provided digitally (e.g., IT services) require fewer locally bound employees. Current analyses show that especially highly skilled employees benefit from this trend as remote working opportunities are increasingly found in this group (Dingel & Neiman, 2020). In addition, employees with remote-working jobs seem to receive higher remunerations (Dingel & Neiman, 2020). Hence, a cross-country relocation of highly skilled employees could – from a country perspective – not only pose risk on revenues from the personal income taxation and the social security system, but also negatively affect spill over effects associated with these

[29] For an overview on the effective tax burden on investments in digital business models, see Spengel et al. (2018).

earners such as higher propensity to consume or the transfer of knowledge (de la Feria & Maffini, 2021). Hence, from this perspective, a reduction in the tax wedges, which are comparatively high in most countries analysed and particularly among Central and Western EU countries, is required to remain or improve the location attractiveness for investments in the knowledge-based, digital economy. As empirical evidence indicates, providing tax incentives for labour is a promising tax instrument, especially for small economies, as the elasticities of worker mobility are particularly high for them. Therefore, they gain most from the introduction of preferential tax schemes for foreigners. However, introducing such incentives are prone to generate tax competition across EU countries (Kleven et al., 2014).

Against the backdrop of increasing restrictions on corporate tax planning as well as the relevance of labour in digitalisation processes, countries might explore new paths to keep or improve their location attractiveness for corporate and labour investments. For example, to avoid an increasing corporate tax burden for domestic MNEs because of the minimum tax, countries could classify existing non-profit taxes as a kind of profit tax to be taken into account when determining the effective tax burden of an MNE within one country. As a different alternative, they could reduce other business charges of MNEs, such as non-wage labour costs, to improve their location attractiveness. In the context of our results, we found a large spread in the effective labour tax burden on the countries concerned (RU: 16.3%; SE: 56.2%) and thus a varying scope for reductions in non-wage tax costs faced by the employer. While the Eastern EU Member states (except Slovenia), Russia and Switzerland pursue a low-tax strategy for employees, the leeway is most limited in Russia and Hungary due to the already implemented flat tax and comparatively low statutory tax rates of 13% and 15%, respectively. In the other countries affected, and in particular, among the Scandinavian countries, being characterized by relatively high EATRs, the burden could be reduced by either increasing the progression schedule at which the proportional (top) tax rates take effect, as well as by introducing or extending existing tax incentives for highly qualified employees. Such – temporarily restricted – preferential tax regimes for highly skilled foreigners in the form of partial tax holidays on labour income or by a favourable flat tax rate are well-established tax instruments (e.g., NL: 1985, DK: 1991, FI: 1999, SE: 2001, FR: 2004, ES: 2005, IT: 2011) among European countries, especially in the Member States with an above-average tax burden to mitigate the negative impact of high taxes on the recruitment of internationally mobile foreigners, especially experts and managers.

2.5. Conclusion

Globalisation has led to a reduction in trade barriers and transportation costs, which has increased capital mobility and the transmission of ideas and meanings through labour mobility. Thus, governments compete on establishing an attractive environment for investments of multinational corporations to strengthen their competitiveness and comparative advantages at the international level. The fast digital transformation process of companies, including a change in employees' working environment, exacerbates the competition among states. To decide on the best location for corporate investments and employing highly skilled employees, multinational firms include tax as well as-non tax factors in their decision-making. According to previous literature, it is well-known that governments lowered especially corporate tax rates over the last decades to attract corporate investments. However, since there is a shift from routine to non-routine tasks in the course of digitalisation, providing an attractive tax environment for highly skilled employees will become increasingly important. Consequently, this study does not only focus on the trends in effective tax burdens of corporations but enriches the analysis by elaborating on a countries' tax environment for highly skilled employees. The synthesis of both indicators provides valuable insights regarding the tax strategy of a country and allows us to draw conclusions on the scope for future tax competitions, including an analysis of ongoing political developments.

Analysing the development of tax burdens on corporations and highly skilled employees for 26 countries from 2009 to 2019, we find that the declining trend in statutory as well as effective corporate tax burdens continues. However, compared to previous works studying a longer time horizon, it turns out that the downward trend of the effective average tax burden on corporations slowed down over the last decade. The results regarding the trends in taxation of highly skilled employees differ significantly compared to the developments on effective corporate tax burdens. While we observe increases in the top statutory tax rates for high-income earners, which in some countries resembles the intention of a wealth surcharge on the superrich, the average effective tax burden on labour for a disposable income of EUR 100'000 remained relatively constant.

The synthesis of both indicators offers additional insights: Eastern EU Member States – except for Slovenia – as well as Russia and Switzerland, impose below-average effective tax burdens on corporations and highly skilled labour. Hence, these countries follow a clear low-tax strategy offering the most attractive investment conditions from a tax perspective. By contrast, Belgium, France, Italy, and Spain can be classified as high-tax countries compared to the sample average, indicating they are least attractive in this context. In addition, several considered countries pursue a mixture of both strategies. Northern EU Member States, as well as Ireland and Slovenia, are characterized by a below-average effective average tax burden on corporations, whereas the less mobile factor labour faces above-average EATRs. The reversed situation can be observed in India, Japan, and the US that tax corporations above and highly-skilled employees below average. Thus, these countries offer attractive investment conditions for one indicator but are less attractive for the other. Overall, we perceive several changes in countries' location attractiveness between 2009 and 2019, leading in parts also to changes in the above-mentioned tax strategies. The reasons for it are twofold: On the one hand, some countries passed tax reforms with significant changes, especially regarding the tax rate, like Denmark, Hungary, and the US. On the other hand, due to the tax competition of several considered countries, passive states, like Brazil or Germany, that lack major tax reforms lost ground and got, in general, less attractive for investments in capital and labour.

In the short run, the corona crisis will affect the future development of corporate tax competition. Necessary measures to delay the spread of the virus have led to a supply and demand shock and a drastic decline in corporate revenues. To counteract the economic consequences of the crisis, governments worldwide have imposed (temporary) tax measures such as extended loss-reliefs, enhanced depreciation regulations, etc., to support the recovery process of corporations. However, the additional government spending has to be financed by fiscal consolidation measures. Therefore, as the crisis hits all economies worldwide, it seems less likely that the race to the bottom concerning statutory tax rates will continue in the near future – we might even observe the opposite. Furthermore, the agreement of over 130 OECD countries on a minimum tax for large corporations might significantly impact corporate tax competition in the long run and can set a new lower bound in the "race to the bottom" regarding corporate tax rates. In addition, the decision on a corporate minimum tax and the fast-approaching digitalisation of firms might shift the focus of tax competition from corporate tax burdens to effective tax levels on highly skilled employees.

3. Measuring Countries' Tax Attractiveness for Investments in Digital Business Models[30]

3.1. Introduction

The digital transformation of the economy is progressing continuously. It revolutionises value creation processes and supply chains, makes production processes smart and promotes the know-how of employees in dealing with innovative technologies. The emergence of new digital business models intensifies competition and has disruptive effects on entire industries (OECD, 2015a). At the same time, the new digital capabilities benefit traditional business models by creating efficiency gains and higher sales potential and act as a catalyst for research and development (R&D) by making innovation processes more dynamic and shortening development cycles. The increased use of (customised) software is a key success factor in value creation.

Investment costs are a decisive factor in the corporate decision-making process. From a business perspective, this also includes taxes. Various scientific studies show that taxes significantly impact international investment decisions, the location of crucial functions and the individual business units' profitability reporting.[31] In the context of digital business models with their high mobility and the possibility to serve international markets without a significant physical presence on site the tax environment at the investment location plays an increasingly important role. Against the backdrop of a fully networked corporate world, the decision on the investment location for a digital business unit such as a digital hub or a platform appears to be much more flexible than a location decision for classic physical production sites. As a result, tax factors are also becoming significantly more relevant for the location attractiveness of digital business models. Thus, it is of primary importance for policymakers to guarantee an appropriate playing field and infrastructure for the digital transformation to advance economic growth and innovation (OECD, 2016).

Although digital business models are highly mobile and can thus exploit country-specific tax regimes in a targeted manner, taxes remain widely ignored in previous studies on location factors for the digital economy. The purpose of this study is to quantitatively analyse the tax

[30] This chapter constitutes a shortened version of the following study: Spengel, C., Nicolay, K., Schmidt, F., Wolf, T., Olbert, M., Steinbrenner, D., Werner, A.-C. (2018). Steuerliche Standortattraktivität digitaler Geschäftsmodelle 2018 – Steuerlicher Digitalisierungsindex 2018.

Retrieved from https://www.pwc.de/de/steuern/pwc-studie-steuerlicher-digitalisierungsindex-2018.pdf (29 September 2021)

[31] See for more details, among others Feld and Heckemeyer (2011).

location attractiveness of countries for investments in digital business models. Thereby we summarize the applicable current tax provisions, i.e., corporate income tax rate, depreciation allowances for digital investment goods, and special regimes for research and development, and show their impact on the effective corporate tax burden which we use as an indicator to measure locations' tax attractiveness. To highlight the tax beneficial environment we compare our results to the one for investments in traditional businesses. Our analysis of the tax drivers is based on two objective measures of the well-established Devereux-Griffith methodology (1999, 2003), the effective average tax rate (EATR) and the cost of capital (CoC). The study covers the EU-28 Member States, Canada, Japan, Norway, Switzerland and the US.[32]

The study thereby delivers novel analysis on the most relevant factors of company taxation influencing investment costs, especially since the resulting effective tax burdens for digital business models differ significantly from the ones for traditional business models. Precisely, our study finds that the different national tax provisions lead to unequal competitive conditions in the internationalised markets. Italy, Ireland and Hungary provide the most attractive tax environment for investments in digital business models and even tax-subsidise them, indicated by negative effective tax burdens. While Germany, the USA and Japan are the least attractive with effective tax rates of over 21%. The low attractiveness of the locations is due to high corporate income tax rates and the low level or absence of targeted tax incentives (R&D credits, special depreciation, lower profit tax rates) for innovative activities related to the digitisation of business models.

Our results thus serve as an objective benchmark for political and corporate decision-makers to evaluate the current tax policy for a given investment location in the course of the digitalisation of the economy. In particular, it reveals tax policy options and the potential need for action to create an attractive tax environment. In extreme cases, the effective tax burden of digital companies in neighbouring industrialised countries can differ by more than 30 percentage points. This can result in unintended tax distortions in investment behaviour due to the high mobility of digital business models.

This study is structured as follows: Chapter 3.2 describes typical types of digital business models and their taxable nexus according to current corporate tax law. Chapter 3.3 explains the methodology used to calculate the effective tax burdens based on the approach of Devereux-Griffith. Chapter 3.4 presents the core results of the digital tax index and their sensitivity to

[32] Regarding the tax provisions for Canada, Switzerland and the US, this study considers the regulation applicable in the province of Ontario, the canton of Zurich and the state of California, respectively.

certain tax provisions considered. Further, we analyse the current German and Swiss tax reform proposal in additional country case studies. Chapter 3.5 concludes.

3.2. Digitalisation of business models and their taxable nexus

3.2.1. Digitalisation and Innovation

Investments in innovations and new, technology-based business models drive the digital transformation (McAfee & Brynjolfsson, 2017). In particular, information and communication technologies (ICT) are considered a key driver of innovation. In 2015, OECD countries invested 2.3% of gross domestic product (GDP) in ICTs, equivalent to 11% of fixed assets. Of this, almost 60% is accounted for by investments in computer software and databases (OECD, 2017b). These investments focus on specific segments such as information technology (IT) security, cloud computing, Industry 4.0, Internet of Things (IoT), as well as Big Data, artificial intelligence and digital platforms (Bitkom, 2017; EFI, 2017; ITU, 2017).

The defining activities in the digitalisation of existing business models and in the creation of new digital ventures are the development of software solutions, the further networking of individual actors and the creation of platforms for the exchange of information as well as for the joint development of new technologies and applications. Companies invest in the development of new technologies as well as the further development of values that have already been created and rely on trained personnel who support digital integration. Value drivers are therefore the development and use of software with the support of the corresponding hardware components. In addition, the creation of intangible value, for example artificial intelligence solutions or proprietary algorithms, relies on the collection, analysis and further processing of large amounts of data and represents a further component in the value creation of digital business models (OECD, 2017b). The focus here is on personal data from customers and users, which is used to further improve digital services and create new innovations (EFI, 2017).

Digital business models and the application of new digital technologies are highly relevant, as the increased networking of individual actors and the improved provision and use of information lead to increased efficiency in production processes and, above all, to product innovations (European Patent Office, 2017). In addition, they enabled a faster adaptation of business models and processes to the needs of users (SVR, 2017). By using digital technologies, companies can expand their revenue streams and compete with purely digital companies (World Economic Forum, 2016). Yet, the potential of these digital technologies can generally only be raised through the parallel deployment of well-trained personnel, which is why these investments are usually linked to the establishment of corresponding human resources (McAfee

& Brynjolfsson, 2017). Overall, investments in digital transformation not only create new jobs and increased trade, but also transform science, government and all industrial sectors (European Commission, 2017; OECD, 2017b; PwC, 2017). However, the Expert Commission on Research and Innovation (EFI) points out for Germany that digital business models and also the application of new digital technologies were neglected in the past, particularly in the ICT sector, due to the focus on the production economy, i.e., Industry 4.0 (EFI, 2017).

Current studies on the influence of ICT and broadband availability underline the economic relevance of investments in innovation and ICT infrastructure. Empirical studies show that their use promotes labour productivity (Bertschek et al., 2015; Grimes et al., 2012). Precisely, Cardona et al. (2013) find that these investments in ICT increase firm-level productivity by 5% to 6%, assessing the findings of several empirical studies on the characteristics and effects of ICT investment.[33] Earlier studies also show that investments in computer equipment and higher personnel expenditure in the IT department increased value-added by almost 10% (Hitt & Brynjolfsson, 1996) and that labour productivity increased, especially in the context of strong people-management practices (Bloom et al., 2012). Further, Akerman et al. (2015) find that this increase in labour productivity, due to the availability of broadband, leads to higher hourly wages and more hiring of skilled workers resulting ultimately in higher business output. In addition, broadband connectivity has positive effects on the innovation activity of companies, both in terms of product and process innovations (Bertschek et al., 2013). Whereas investments in ICT seem to increase productivity, investments in R&D primarily lead to more innovations (B. H. Hall et al., 2013). Investments in R&D are further intensified by a diversified business landscape (i.e. heterogeneity of firms), which leads to greater long-term growth (Chun et al., 2014). Moreover, investments in ICT makes firms more resilient in times of crisis (Bertschek et al., 2019).

3.2.2. Classification of digital business models and their taxable nexus

Given the highly dynamic and increasingly complex development of technological progress, digital business models can take various organisational and legal forms (El Sawy & Pereira, 2013). However, digital business models are characterised by the fact that they primarily distribute digital products and services based on digitised information through various non-physical channels (Hoffmeister, 2015). Following the classification of Olbert and Spengel (2017), we identify three types of business models that deserve attention from a tax

[33] See also Clarke et al. (2015), and Bertschek and Niebel (2016).

point of view: the domestic investment in the digital transformation of traditional businesses, the investment in a cross-border digital business-to-consumer (B2C) business model and the cross-border digital business-to-business (B2B) business model.

In 2018, the digital transformation of almost the entire value chain is already taking place in companies in all sectors, to varying degrees. Disruption is a prominent buzzword for the intention of traditional industrial companies to renew their business models by investing in digital technologies. It is to be expected that the value creation process in general will change in many companies (e.g. Industry 4.0), horizontal and vertical networking will become more pronounced and new products and business areas will be established. The object of digital transformation is the integration of digital technologies into the existing business model with the aim of increasing value creation for the customer, the company itself and other stakeholders, which should ultimately lead to increases in profitability (Schallmo & Williams, 2018).

Within companies, digital transformation in traditional companies will go beyond isolated projects and initiatives in separate business units and create a digitised enterprise. This includes a change in the way managers and employees work and think (IDC, 2016). Currently, many companies with traditional business models are initiating this process with innovation centres (often in the form of spin-offs). A study by the World Economic Forum (2016) describes this process as a strategically sensible way of not exposing the main business to too great a risk and of driving forward the digitisation of the business model gradually and with flexibility without being restricted by organisational structures. In addition, companies with innovation centres acquire or finance other smaller companies and develop ideas and products in an international and open atmosphere while drawing on the infrastructure of the parent company.[34]

Hence, we consider the digital transformation of a traditional, industry-based business model as a separate business model. In this way, our study not only captures start-ups whose business models originated with the penetration of the internet, but offers insights into the fiscal framework for companies of all industries and sizes that are digitising their business processes, offer digitised solutions[35] and are internet-based (Bundesministerium für Wirtschaft und Energie, 2015).[36]

[34] In contrast to large firms, SMEs tend to rely on open digital innovation hubs to adapt digital technologies (Crupi et al., 2020).

[35] Examples for such solutions are “senseManagement” by Hagleitner (http://haleitner.com/en/products/wash-roomhygiene/hagleitner-sensemangement/) and “Parking lot sensor” by Bosch (https://www.bosch-connectivity.com/de/produkte/connected-mobility/parking-lot-sensor/downloads/).

[36] See also EFI (2017) for such a global understanding of digital business models.

A taxable nexus in the context of these digital transformations often exists only in the state of residence of the company or the spun-off company. Based on the current state of research, the latter is usually resident in the state of the parent company, but can also operate from a specific geographical market. It does not matter whether turnover is achieved with customers in Germany or abroad. Since the entire investment activity as well as the taxable nexus in this type of business model are considered at the location of the main company, this model is also referred to as "domestic" in the following.

Furthermore, digital business models are often observed in the context of cross-border investment and sales activity. Thus, our distinction between B2B and B2C models continues to be of high practical relevance, as the sales structure and the customer segment have a formative influence on the entire business model, especially with regard to product policy and sales strategy (Homburg, 2017). At the same time, the distinction in the cross-border case is relevant for the tax consequences and can be transferred to business models in different forms.

Digital business models in the B2C segment are characterised by private end users who are either direct, paying customers or contribute significantly to the value proposition for commercial customers through their activity within the business model. Classic representatives of digital B2C business models are search engines, streaming services or online shops. To carry out functions of local user support and marketing and contract initiation local subsidiaries and branches could be established, which are equipped with a limited infrastructure for accessing and operating the platforms. Yet, direct sales characterise this cross-border sales structure. Parent companies directly conclude contracts with third parties across borders, so that there are hardly any intra-group payments. Therefore, the majority of the activities including relevant corresponding investments to the business model are carried out in one place, independent of the sales market.

A taxable nexus hence arises primarily in the state of residence of the business entity that makes the investments in the platform and the digital products, employs the staff to perform the central activities and directly collects the revenues. If there is a significant sales market, a taxable nexus could arise through the establishment of the subsidiary. However, only a minimal income margin is allocated to the subsidiary due to the applied cost-plus method. This reflects the outlined personnel functions, assets and risks which are tied up with the main company. As a result, the tax provisions in the foreign sales market only play a subordinate role.

Lastly, we account for the B2B segment which includes those business models of companies that offer digital products or services exclusively for commercial customers and thus contribute to the digitalisation of their customers' business model (BDI & PwC, 2015). In particular, the use of digital products and services leads to the development of new business processes and fields as well as higher efficiency and flexibility. It is often geared towards providing digital solutions increasingly through online access via a cloud portfolio and a database platform in order to increase the innovative power and agility of their customers. Therefore, the infrastructure consists of a complex combination of hardware (data centres) and software. One of the core activities, software development (R&D), takes place at the parent company with its massive server landscapes. To legally bundle the results of R&D activity it is often centrally coordinated in one place. Besides the investment costs for the data centres, personnel costs for R&D and sales are the largest cost factor. Revenues are generated in the form of service fees, user fees or licences, depending on the product segment and the type of transaction with the customer. In the B2B segment, local sales and service activities are more pronounced than in the B2C segment due to the higher complexity and the higher degree of individualisation of digital services and products. Thus, local units regularly enter into direct contractual relationships with customers. The commercial use and resale of intangible goods developed throughout the group usually results in intra-group remuneration in the form of licences, commission agent structures or internal cost allocations.

Due to the more demanding organisational distribution structures, a taxable nexus arises for digital business models in the B2B segment in the state of residence of the parent company as well as in the market state. Although the market state generates a large part of the turnover, the tax regulations in the parent company’s residence country are of particular relevance. Due to the organisational structure described above, intra-group transactions result in a profit allocation in favour of the parent company. While the parent company invests in its own server infrastructure and manages intangible rights centrally, local distribution companies are only equipped with very few fixed assets.[37]

To summarize, digital business models usually have a lean corporate structure as well as high flexibility and mobility of the main activities and capital goods. Data-centric business models in particular resort to a decentralised value creation architecture (for more details, see Dorfer, 2018). This results in a taxable nexus in the state where the company locates its core activities. Serving global markets is often only associated with a small location of activities and capital

[37] As a local sales company, SAP Österreich GmbH has almost no intangible assets and the fixed assets of 1.7 million euros consist almost exclusively of operating and office equipment with sales revenues of over 220 million euros in 2015. The fact that these assets are concentrated at a few main locations is shown by the balance sheet sizes of the respective affiliated companies of the SAP Group (approximated by equity, SAP SE (2016)).

goods in these countries, which means that only a small share of the total group profit is allocated to the units in these countries.

Hence, digital business models indicate a potentially very high mobility of their main activities, which is why the tax framework can be a significant location factor with regard to the investment decision as well as the headquarters of companies. Since human resource functions regularly fall within the scope of software development, incentives for R&D can play a special role. In addition, the success of digital business models depends to a large extent on highly qualified workers, who are exposed to different levels of wage tax burdens depending on the location of their activities. As a result, national tax framework conditions at the company and employee level should be decisive for the attractiveness of a location.

3.3. Methodology and adjustment for digital business models

3.3.1. Devereux-Griffith Methodology

The methodology of Devereux and Griffith (1999, 2003) is used to calculate the tax effective measures. This methodology allows us to take into account a variety of tax parameters and to quantify their impact on a hypothetical investment in a given country. Further, it allows us to include special regulations for the assets considered, such as R&D tax incentives and IP box regimes. The country-specific regulations on tax rates and the tax base can thus be represented in single parameters. These parameters can then be used to compare country's tax environment and to analyse its attractiveness for investing in digital business models since an investment with identical pre-tax parameters may realize different after-tax returns depending on the investment location. In addition to domestic companies, cross-border investments can also be considered depending on financing and profit repatriation. Starting from the basic scenario, which is used in numerous studies to measure the effective tax burden of the manufacturing sector (Spengel et al., 2021), we make special assumptions and modifications of the underlying formulas for investments in digital business models for this study.

The Devereux-Griffith approach is based on a neoclassical investment model that distinguishes between marginal investments that just yield their cost of capital and profitable investments. The CoC reflects the minimum rate of return before taxes required by an investor to conduct the investment. If taxation causes the CoC to rise above the real market rate, the marginal corporate investment is discriminated and theoretically, taxation exerts an influence on the optimal level of investment activity. Thus, a lower CoC suggests a more attractive location for expanding the investment volume in a given location.

Within the digitalisation of the economy, where one expects increasing rate of returns, the effective tax burden on profitable investments should be decisive for most investment decisions such as the location of subsidiaries or the choice between different production technologies. The effective average tax rate (EATR) indicates the effective tax burden on such an infra-marginal investment and thus the tax attractiveness of a location. Precisely, the EATR measures the tax-induced reduction of the net present value (NPV) of profitable investments. When choosing between two or more mutually exclusive profitable investments, a company will favour the alternative with the highest post-tax net present value. It is computed as the difference of NPV before and after taxes (denoted by R^* and R)[38], divided by the discounted pre-tax rate of return p:

$$EATR = \frac{R^* - R}{\frac{p}{1-r}} \tag{4}$$

The calculation of the NPV after taxes (R) is in the core of our analysis. In general, it is defined as:

$$R = -(1-A) + (1-\tau)\frac{(p+\delta)(1+\pi)}{1+i} + (1-A)\frac{(1-\delta)(1+\pi)}{1+i} \tag{5}$$

where A denotes the NPV of tax allowances, τ the applicable corporate income tax rate, p the pre-tax rate of return, δ the economic depreciation rate, π the inflation rate and i the nominal interest rate[39]. The first term captures the initial investment outlay, which is reduced by the NPV of the capital allowances for the investment asset. The second term reflects the real financial return and the wear-off of the asset realized in the next period, which is subject to taxation. The final term accounts for the fact, that we assume a one-periodical investment which is dissolved after one-period.

3.3.2. *Adjustments for Digital Business Models*

To evaluate the location tax attractiveness for investments in digital business models across countries, we adjust the basic structure of the model.[40] We assume that a tax nexus arises at the investment location and the location of international expansions according to prevailing rules and that the respective local tax framework conditions are decisive. Through this, we depict the tax consequences of real investment decisions.

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[38] The NPV before taxes (R^*) equals the economic rent of the investment and is defined as: $R^* = \frac{p-r}{1+r}$.

[39] The nominal interest rate is defined as: $i = (1+r)(1+\pi)$.

[40] Legal and organisational structures with the purpose of international tax planning are not taken into account.

In our baseline scenario, the domestic digital transformation of traditional businesses, we, therefore, adjust the considered asset mix of the underlying investment. In doing so, we treat the digital transformation as a separate investment project. To account for the core activities of digital business models including R&D activities, especially software development (EFI, 2017; European Patent Office, 2017; OECD, 2017b) in combination with the deployment of hardware components and distribution activities, we consider software, hardware and intangible assets as representative digital capital goods.[41] Our baseline scenario thus reflects common business practice of companies which regularly set up innovation centres in close proximity to headquarters to foster the digitalisation of their core functions and processes.

Following chapter 3.2.2, we extend the baseline scenario for two simplified cross-border scenarios by assuming either an investment in foreign service companies (B2C) or sales companies (B2B).[42] Nevertheless, the core activities and thus the primary investments in digital assets remain at the parent location. While multinationals serve foreign customers by setting up local subsidiaries, which only perform limited staff functions and invest only in the most necessary IT infrastructure. We account for this lean organisational structure and the applicable cost-plus method in the calculation of the effective tax burden for the case of B2C by a weighted average of the ratios of the parent company (80%) and the subsidiary (20%).

In contrast, the multinational grants the local B2B subsidiary rights to use software and other intangible assets to generate revenue. To account for this commercial exploitation of patented intangible assets or copyrights in the case of software, we assume that the subsidiary owes a licence amounting to 80% of the return achieved in the basic case to the parent company. Hence, 20% of the returns are taxed in the market state and 80% as royalty income at the domestic parent company. We further assume that after-tax profits are distributed as dividends to the parent company. The royalty payments as well as dividends could give rise to additional withholding taxes.

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[41] Hardware refers to the various components of the ICT infrastructure, including computers, accessories and databases. The tax valuation of intangibles (specifically acquired patents) is applied accordingly in the present calculations; see Spengel et al. (2021), Section A.

[42] For more detailed information, please refer to Spengel et al. (2018, Chapter 1.3).

For the purpose of this study, we follow existing literature and employ the same economic conditions as depicted in Table 4, which allows us to compare our findings to existing studies.

Table 4: Parameters of Devereux-Griffith methodology (in %)

Economic parameters	
True economic depreciation rate (%)	
intangibles (acquired, self-developed)	each 15.35
hardware, software (acquired, self-developed)	each 17.5
real interest rate (%)	5
inflation rate (%)	2
pre-tax rate of return for EATR (%)	20
Composition of investment	
Weighting of investment (%)	
acquired IP, self-developed IP, acquired software, self-developed software, hardware	each 20
Weighting of financing (%)	
retained earnings	55
new equity	10
debt	35

Source: own composition based on Spengel et al. (2021)

3.4. Results

3.4.1. Digital Tax Index: Location Tax Attractiveness

We first present the main results of the overall digital tax index, which consolidates the insights of for the cross-border business models B2C and B2B as well as for the activities related to the transformation of traditional business models. Next to the EATRs, the cost of capital (CoC) and the corresponding ranking positions are listed. The final ranking is calculated from the most favourable tax case in each country (best case), taking into account tax incentives for R&D and IP box regimes depending on their applicability to the digital business model. The absolute ranking of the countries results from the unweighted average of the effective average tax rates (EATR) of all three business models presented in the sub-indices:

$$EATR_{Digi} = \frac{1}{3}EATR_{Best\ Case\ Domestic} + \frac{1}{3}EATR_{Best\ Case\ B2C} + \frac{1}{3}EATR_{Best\ Case\ B2B} \quad (6)$$

$$CoC_{Digi} = \frac{1}{3}CoC_{Best\ Case\ Domestic} + \frac{1}{3}CoC_{Best\ Case\ B2C} + \frac{1}{3}CoC_{Best\ Case\ B2B} \quad (7)$$

Table 5 shows that the effective average tax burden of digital business models is on average significantly lower than the effective tax burden of traditional business models. In the countries studied, the average EATR amounts to just under 9% and is thus more than 12 percentage points lower compared to the traditional, domestic business model. The CoC is also noticeably lower for digital business models. On average, it amounts to 3% for digital business models and is thus 3 percentage points lower than for traditional ones. Due to the lower effective tax burden, investing in a digital business model is correspondingly more attractive from a tax perspective than investing in traditional businesses. If a country improves its ranking, this means that the attractiveness of a location for digital business models is higher. The different EATRs imply a differentiated tax attractiveness of the countries in an international comparison, while the reduction in the CoC suggests that higher investments in digital than in traditional business models are to be expected.

The main factors influencing the effects compared to the results for traditional business models are tax base regulations and special tax regimes. In the majority of countries the tax treatment of capital goods of digital business models is more favourable than the treatment of traditional capital goods. This is because the tax depreciation rules for acquired software and hardware provide for a shorter depreciation period than for conventional capital goods. In addition, the costs of investing in the in-house creation of software and other intangible assets are current costs that are regularly immediately deductible. The self-production of such intangible assets is included at 40% in the weighting of capital goods in this study. This contrasts with the capitalisation rules for investments in traditional assets, as assumed in the case of the traditional business model (see subchapter 3.4.2.1). The special tax regulations for R&D activities and the realisation of profits from the use of intangible assets reinforce the effects (see subchapter 3.4.2.2).

However, the effective tax burden strongly differs according to the location considered. Italy being the most tax attractive location for digital investments provides an EATR of -33.2% (CoC -8.9%), while digital investments in Germany, Japan and the US (before the 2018 tax reform)[43] face an average effective tax rate of up to 22% (CoC: up to 4.9%). The top position of Italy and the clear gap to second-placed Ireland (difference of around 30 pp) are due to the very favourable depreciation rules for digital capital goods introduced in 2017 as well as R&D incentives. In addition, the IP box applies to both types of income (licences and sales), resulting in a low tax burden in all three business models. Despite the relatively high profit tax rate, digital business models in Italy thus reduce the EATR by over 56.6 percentage points and the CoC by over 14.7 percentage points compared to the traditional, domestic business model. It should be noted here that the coexistence of different support measures leads to the result that the support for such investments overshoots (for a differentiated effect of the Italian support

[43] For more details on the impact of the US tax reform of the tax location attractiveness, see Spengel et al. (2018, Chapter F 3).

measures, see Subchapter 3.4.3.3). In practice, however, it may be the case that a company does not benefit fully from all the advantageous schemes at the same time.

Ireland, Hungary, Lithuania and Latvia, following on ranks 2 to 5 with an EATR of 0% or even slightly negative EATR (i.e., IE and HU), are also attractive investment locations in the traditional ranking due to low profit tax rates. In addition, all countries have R&D tax incentives that lead to a strong decrease in EATR for digital business models (-11.6 to -17.5 pp) due to their broad designs. In addition, generous IP box regimes exist in Ireland and Hungary.

Positions in the mid-range of the ranking are held by typically low-tax countries such as Eastern European countries, Luxembourg and Cyprus as well as traditionally high-tax countries such as Portugal, Spain, France, the UK, Norway and the Netherlands, which can improve their ranking for digital investments due to special tax regulations (reduction of the EATR by 13.1 to 26.7 pp).

With an EATR of 22.2%, Germany is in last place, just behind Japan and the USA. One reason for the lower ranking is the traditionally high tax level in these countries. Beyond that, there are only moderate (i.e., JP and the US) or no R&D tax incentives (i.e., DE). Despite significant reductions in their effective tax burden, these countries cannot improve their relative location attractiveness for investments in innovative, digital business models due to the comparatively higher reduction in the EATR of other high-tax countries, but rather fall behind, as in the example of Germany.

We observe a similar diverse picture for the tax location attractiveness if one focuses on the CoC. While the average CoC amounts to 3.0%, being already significantly below the alternative benchmark investment of 5.0%, we even observe negative CoC for Italy (-8.9%) and France (-0.3%). This indicates that investments in digital business models are on average treated in a tax-advantaged way compared to the alternative financial market investment. Said differently, shareholders in these countries require a lower minim pre-tax rate of return to stay competitive with the alternative investment. Still, we note that several countries yield a CoC of more than 5.0% (i.e., BG, CH, EE, FI, and SE), suggesting that in these location it is not attractive to increase the investment volume for digital business models, at least from a tax perspective.

Table 5: Digital tax index 2018

		EATR				CoC			
Country		**Rank**	**Ø**	**Δ Rank**	**Δ in pp**	**Rank**	**Ø**	**Δ Rank**	**Δ in pp**
Italy	IT	1	-33.2%	22	-56.6	1	-8.9%	16	-14.7
Ireland	IE	2	-3.4%	3	-17.5	6	2.2%	4	-3.5
Hungary	HU	3	-0.5%	-1	-11.6	11	3.0%	-2	-2.7
Lithuania	LT	4	0.0%	0	-13.7	7	2.2%	-1	-3.4
Latvia	LV	5	0.1%	1	-14.8	8	2.2%	3	-3.5
Croatia	HR	6	4.5%	2	-10.3	10	2.7%	-6	-2.6
Romania	RO	7	5.4%	0	-9.3	14	3.3%	-6	-2.4
Portugal	PT	8	5.5%	9	-14.6	4	0.8%	-3	-3.6
Spain	ES	9	5.5%	20	-24.6	3	0.2%	27	-6.8
France	FR	10	6.7%	21	-26.7	2	-0.3%	29	-7.5
Czech Republic	CZ	11	7.2%	-1	-9.5	13	3.2%	-6	-2.4
UK	UK	12	7.4%	7	-13.1	21	3.9%	6	-2.7
Norway	NO	13	7.9%	8	-14.8	9	2.4%	15	-3.8
Cyprus	CY	14	8.5%	-11	-4.5	26	4.7%	-23	-0.6
Netherlands	NL	15	8.7%	5	-13.8	16	3.5%	4	-2.5
Bulgaria	BG	16	9.2%	-15	0.2	31	5.1%	-26	-0.2
Poland	PL	17	9.5%	-5	-8.0	20	3.8%	-5	-2.0
Luxemburg	LU	18	9.8%	6	-13.9	27	4.8%	-8	-1.1
Slovenia	SI	19	9.9%	-8	-7.4	22	3.9%	-9	-1.9
Slovakia	SK	20	10.0%	-6	-8.7	17	3.5%	-3	-2.2
Belgium	BE	21	12.6%	7	-16.8	18	3.6%	5	-2.5
Malta	MT	22	12.8%	8	-19.4	5	1.4%	24	-5.4
Canada	CA	23	12.8%	2	-11.4	15	3.5%	10	-2.9
Denmark	DK	24	14.5%	-6	-5.6	24	4.5%	-6	-1.4
Austria	AT	25	14.8%	-3	-8.3	23	4.1%	-1	-2.1
Switzerland	CH	26	15.6%	-13	-3.1	29	5.1%	-17	-0.6
Estonia	EE	27	16.0%	-18	0.3	32	5.2%	-30	0.1
Finland	FI	28	16.2%	-12	-3.4	33	5.3%	-12	-0.8
Sweden	SE	29	16.4%	-14	-3.1	30	5.1%	-14	-0.7
Greece	GR	30	16.4%	-4	-11.2	19	3.7%	9	-2.9
Japan	JP	31	21.2%	1	-13.1	25	4.6%	8	-3.5
US	US	32	22.0%	1	-14.6	12	3.1%	20	-4.5
Germany	DE	33	22.2%	-6	-6.6	28	4.9%	-2	-1.6
Average			**8.8%**		**-12.4**		**3.0%**		**-3.0**

Notes: This table presents the results based on the tax provisions as of 1 July 2017. A rank of 1 indicates the most attractive tax provisions for investments in digital business models.
Source: own calculation and composition

The analysis of the overall index highlights that the ranking according to the EATR and the one according to the CoC strongly deviate for countries with high statutory corporate tax rates but generous tax provisions regarding the determination of the tax base of digital investment assets, and especially R&D tax incentives (e.g., FR, GR, MT, ES and the US). These latter countries are attractive for marginal investments. The opposite holds for investments in countries with low to moderate statutory corporate tax rates (e.g., HU, RO and the UK), which lead to a favourable position regarding profitable investments but still relatively high CoC. The differences between the rankings are of similar magnitude in countries with low statutory corporate tax rates but no incentives for R&D (e.g., BG, CY and LU).

Deviations between the rankings according to the EATR and the cost of capital can arise since the relevant tax influencing variables differentially affect marginal and profitable investments. While the EATR strongly reflects the statutory corporate tax rate, the CoC is primarily driven by the depreciation allowances, i.e., the tax base provisions. In the following subchapters we have a more detailed analysis of these tax drivers.

3.4.2. Sensitivity to tax base effects – Accelerated depreciation and R&D tax incentives

To simplify the analysis for tax drivers we focus on the domestic case, reflecting the digital transformation of manufacturing companies. Still, we observe differences of the sub-index of the domestic investment in contrast to the overall index since both cross-border scenarios add an additional layer of taxation. However, the domestic tax burden is a major driver of the effective tax burden as the relevant investments and activities of the MNE take place in the parent company's country. Thus, it is not surprising that we observe a correlation of 85% for the overall digital tax index results and the best-case scenario of the digital transformation.

3.4.2.1 Effective tax burden comparison of manufacturing vs. digital business models

The determination of the tax base focuses on the tax treatment of investment costs, i.e., the acquisition or production cost for the employed investment assets. Hence, it is a relevant factor influencing the effective tax burden and thus the tax attractiveness of a location.[44] The treatment of capital goods is all the more relevant for the effective tax burden of investments with a low pre-tax rate of return (Spengel, 2003), i.e., the CoC. To highlight the impact of the tax base effect, we compare the case of digital transformation with an investment in a traditional manufacturing asset mix (e.g. buildings, machinery, acquired intangibles, inventories, and financial assets).[45]

Investments in the baseline scenario of the (domestic) digital transformation face an average effective tax burden of 17.5% (see Appendix 6). This EATR is nearly twice as high as the overall result of the digital tax index, due to missing R&D tax incentives.[46] Yet, we note an

[44] We further consider regulations on the deduction of interest in the case of debt financing or the deductibility of individual types of tax determining the taxable profits. Since, these regulations apply for both digital and traditional business models, we do not explicitly discuss them here. For more details, see Spengel et al. (2021).

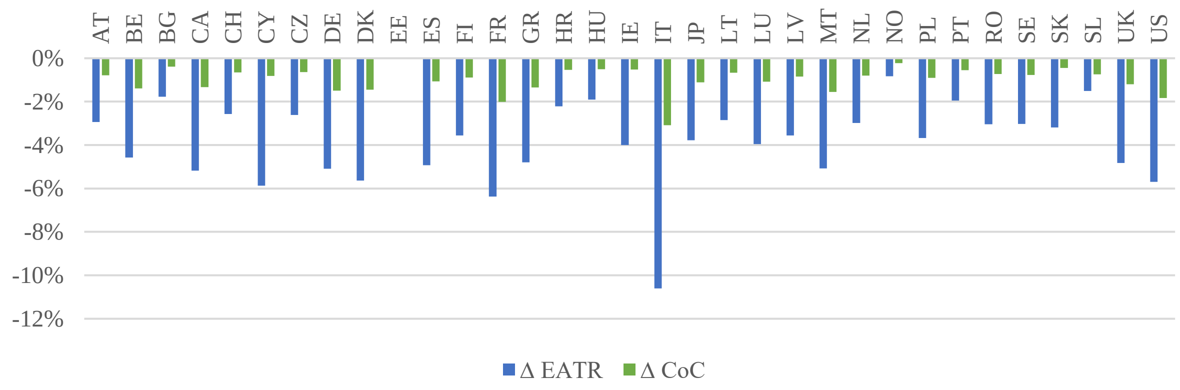
[45] For the provisions on depreciation allowances for movable fixed assets see Spengel et al. (2021, sec. A).

[46] For more details on the impact of R&D tax incentives, see subchapter 3.4.2.2.

average decline in EATR (CoC) of 3.8 percentage points (-1 pp) when analysing only the change in asset mix for a domestic digital company relative to the manufacturing sector. Except for Estonia[47], both effective tax burden measures on digital investments are always lower than for the traditional manufacturing investment. However, there is significant variation within the locations considered. For example, the decrease in EATR (CoC) ranges from -10.6 (-3.1) percentage points in Italy to -0.8 (-0.2) percentage points in Norway.

The reduction in the effective tax burden roots in the generous depreciation rules for the digital assets considered. Especially, for self-developed software and intangible assets the major cost factor is personnel costs, which are current and (mostly) immediately tax-deductible costs. The same applies to other current expenses related to the in-house production of software and intangibles assets. Exceptions to the general rule exist in Norway, Portugal and Slovenia, which capitalize development costs of self-developed intangible assets (including software) and depreciate them in subsequent periods analogously to acquired intangible assets.

Figure 7: Difference in effective tax burden measures of digital transformation or classical manufacturing



Notes: For the computation of the change in effective tax burden measures, we consider the effective tax burden of the domestic digital transformation and the effective tax burden on a traditional manufacturing investment based on Spengel et al. (2021).
Source: own illustration and calculation

Further, we observe more generous depreciation allowances when comparing the depreciation provisions for capitalized assets (i.e., hardware, software, and intangible assets) to traditional investments assets for manufacturing.[48] Overall, 20 (21) of the 33 countries considered apply separate depreciation rules for purchased software (hardware). These provisions include accelerated depreciation schemes or higher depreciation rates compared to those applicable to

[47] Estonia has no special provisions for depreciation or deduction of investment costs due to its distribution tax system.

[48] For an overview on the depreciation allowances for (capitalized) software refer to Appendix 10 and for hardware to Appendix 11.

standard fixed assets of traditional business models[49] (e.g., machinery or plant and equipment).[50] In Denmark and Cyprus (for application software up to 1,708 euros) even an immediate deduction is possible.

Italy significantly improves its locational attractiveness in terms of CoC and EATR, strictly followed by Denmark. The recently introduced special tax provision for investments in Italian high-technological and digital assets (150% additional hyper-deduction for tangible assets and 40% additional depreciation allowance for software) result in an improvement of 14 positions in the ranking compared to the ranking of traditional manufacturing (reduction of the CoC of 3.09 pp, 16 positions improvement). The Danish EATR decreases by 5.6 percentage points and improves Denmark's location attractiveness by 6 positions in the ranking, due to the immediate deduction for all expenses, i.e. also acquisition costs for purchased software and hardware. The CoC also decreases by almost 1.5 percentage points and leads to an improvement of 15 positions in the ranking. Thus, Denmark is one of the most fiscally attractive locations for marginal investments. Similar effects can be observed to a lesser extent in Belgium, France, Germany and Luxembourg which improve by at least 10 positions due to a reduction in the CoC, while their relative tax attractiveness according to the EATR remains similar. Norway exhibits the smallest change in effective tax burden, as there are only slightly improved depreciation conditions for hardware in addition to the capitalisation requirement for self-constructed assets.

Basically, the faster a capital good can be depreciated or the earlier the acquisition or production costs reduce the tax base, the more attractive the regulation is from a tax perspective. This means that the immediate deduction or the increased depreciation rates for software and hardware are advantageous in a country comparison, and the resulting deviations from the treatment of traditional capital goods make investments in such digital goods more attractive in the respective country. The tax profit determination rules in Denmark, Italy, Latvia, Poland and Cyprus are particularly attractive. Whereas, digital business models encounter the least

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[49] For a detailed overview on depreciation allowances for traditional business assets considered in our comparison group of manufacturing EATRs, see Spengel et al. (2021).

[50] Several countries relying on straight-line depreciation for software and hardware nearly half the depreciation periods compared to traditional fixed assets considered (e.g. BG: 2 vs. 3 years; DE: 3 vs. 7 years; GR: 5 vs. 10 years; PL and SL: 2 vs. 5 years, CY: 3 vs. 10 years). Other countries, introduce higher depreciation rates for their declining balance depreciation (e.g. CA: 30% vs. 25%; LV: 70% vs. 40%; CH: 40% vs. 30%) or even switch to straight-line depreciation (LT: SL 3 years vs. DB 40%; PT: SL 3 years vs. DB 35.7%; CZ: SL 3 years vs. DB 30%; and US: SL 3 years vs. DB 4% to 29%).

attractive tax treatment rules for capitalised ICT assets in Ireland, Japan, the Netherlands, Austria and the UK.

3.4.2.2 R&D Tax Incentives

A core activity of digital business models lies within the development of existing and new products, services and processes, especially the development of software and the digitalization of processes along the entire value chain of the business. Given that R&D activities are associated with extensive expenditures, mostly personnel expenses, tax incentives for R&D are an important tax-related location factor for digital business models. R&D costs qualifying for the incentive mechanisms are generally defined according to the Frascati Manual by the OECD (OECD, 2015c) and capture basic research, applied research and experimental development. Development costs related to the creation of intangible assets are usually covered by existing R&D tax incentives. If activities and related costs of software development, software usage, platform and process development, as well as other activities involved in the digital transformation of business models, are captured, digital business models can benefit the most from R&D incentives.

R&D tax incentives differentiate in principle between input and output promotion. Input-based R&D tax incentives can target either the tax base (e.g. accelerated depreciation and super deductions) or directly the tax liability (i.e. tax credits). Among the countries analysed, 24[51] offer fiscal incentives with differences in the incentive rate, the qualifying expenditure and the qualifying activity (see for more details, Appendix 12). More than half of the countries apply a tax credit (i.e., AT, BE, FR, IE, IT, JP, CA, MT, NL, NO, PT, ES, UK, and the US) with tax credit rates ranging from 4.59% in Belgium to 50%[52] in Italy. The majority of countries relies on a volume-based tax credit, thus benefitting all eligible R&D expense of the fiscal period. Whereas, Italy, Japan and the US rely on a pure incremental scheme which only applies to the increase in R&D expenses relative to a reference period. Interestingly, we observe that mostly the smaller economies rely on enhanced deductions (CZ, GR, HR, HU, LV, LT, MT, PL, RO, SL, and SK) to stimulate additional R&D activity. Malta is the only country which offers both types of R&D tax incentive depending on the investment asset considered.

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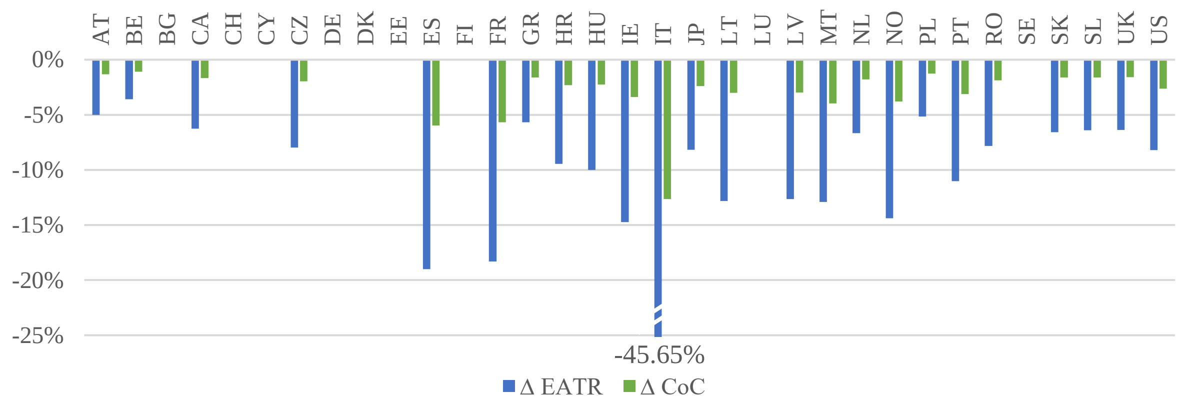
[51] Denmark already provides for an immediate deduction for all assets in the standard digital case.

[52] The credit rate refers to volume-based R&D tax credits. Additionally, incremental tax credits exist in, e.g., Portugal with a rate of 50% and Spain applying a rate of 42%.

Figure 8: Difference in effective tax burden measures considering R&D tax incentives



Notes: For the computation of the change in effective tax burden measures, we consider the full amount of our (incremental) hypothetical investment as eligible expenses for incremental tax credits in IT and the US. Similarly, we apply the higher rate for incremental tax credits for hybrid tax incentives in ES and SK. In case investments do not exceed the reference threshold, the results of the standard digital transformation case without R&D tax incentives apply.
Source: own illustration and calculation

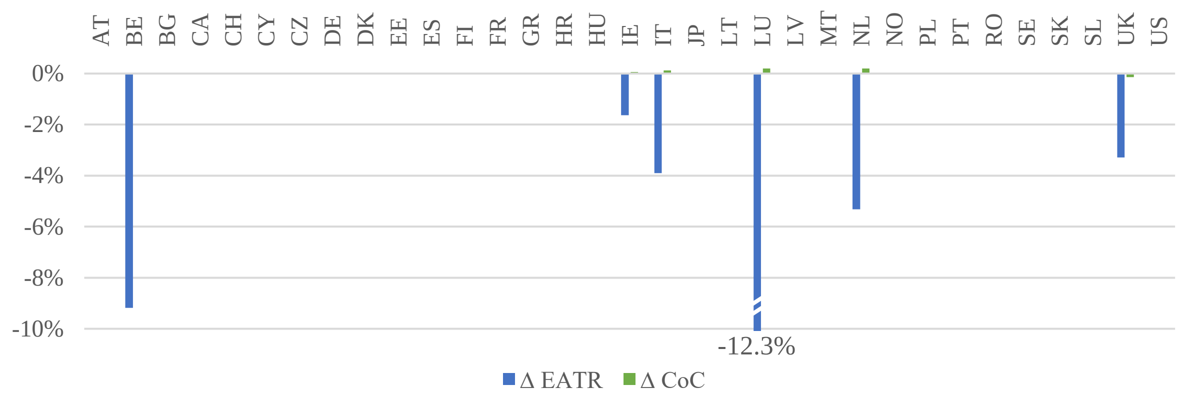
The large decreases in the EATR of more than 10 percentage points in several countries (i.e., ES, FR, HU, IE, IT, LT, LV, MT, NO, PT) reflect not only the generous tax credit rates but also the extent of qualifying expenditures. While R&D personnel expenses fully qualify for R&D tax incentives in all countries considered, depreciation allowances for hardware and software qualify only in 15 and 9 countries respectively. Italy sticks out with huge reductions in both effective tax burden measures, which result in a CoC of almost -10% and a negative EATR of -32.8%, indicating an implicit subsidy for R&D projects (see Appendix 7). Both extreme effects are caused by the generous design and scope of the Italian tax credit scheme. Some countries offering generous R&D tax incentives together with a rather low statutory tax rate (e.g., UK) face a reduction, which is not sufficiently large to improve their relative tax attractiveness in the international comparison. Countries without R&D tax incentives and rather high statutory tax rates (e.g. CH, DE, SE) further lose ground in the international tax competition on highly mobile digital investments.

Besides the classical input-oriented R&D tax incentives, several European countries rely nowadays on a reduced profit tax rate on IP income. Among the 33 considered, 13 countries have implemented IP box regimes in 2017.[53] The average IP box rate across these states is 7.95% and ranges from 0.00% in Malta to 16.76% in France. The attractiveness of these IP box regimes heavily depends on their definition of qualifying IP assets, the scope of eligible income

[53] The analysis includes the IP box regime in the Swiss canton of Nidwalden, while the standard tax parameters refer to the provisions in Zurich. When one considers only the rules applicable to investments in Zurich, the results in the standard case without the implementation of the IP box apply.

and the treatment of current and past R&D expenses incurred in the creation of the intangible (for an overview, see Appendix 13). While all IP boxes cover self-developed patents, less do so for self-developed software and the minority further includes acquired intangibles.

Figure 9: Difference in effective tax burden measures considering IP boxes



Notes: For the computation of the change in effective tax burden measures, we only consider IP box regimes including notional royalties in the scope of eligible IP income. Doing so, we do not cover the change in effective tax burden for the IP boxes in CH, CY, ES, FR, HU, MT, and PT.
Source: own illustration and calculation

In addition, the scope of eligible income varies significantly across countries. All IP box regimes apply to royalty fees generated by licensing IP to other parties. However, the IP can also be used internally to improve processes and products to generate higher sales. 6 of the 13 European IP boxes consider such notional royalties. To differentiate between the generosities of IP boxes, we assume within this project that domestic IP boxes can only benefit from IP boxes if they include notional royalties in the scope of eligible income as they do not receive any royalty income.[54] Besides the scope of income, the treatment of expenses determines the attractiveness of the IP box regimes. As of 2017, only France, Hungary and Portugal apply the gross principle, where cost are deductible at the regular corporate income tax rate. All other IP box countries comply with the OECD modified nexus approach by applying the net principle such that the costs are deductible at the reduced IP box rate.[55] Thus, the gross principle is the more beneficial provision, resulting in a larger reduction of the EATR (see Evers et al., 2015).

Figure 9 shows the strongest reductions in the EATR for Belgium (-9.18 pp) and Luxembourg (-12.25 pp), reflecting the significant reduction in the applicable profit tax rate of -28.89 and

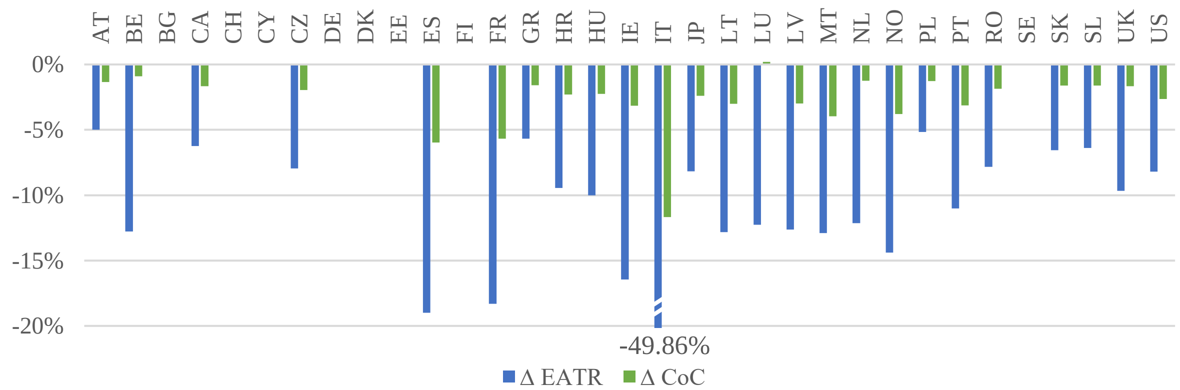
[54] For more information on the cross-border cases, see Spengel et al. (2017; 2018).

[55] Within the development phase incurred cost for the development of the intangible asset have been deducted at regular corporate income tax rate. Thus, these costs are recaptured, i.e., added back to the regularly taxed income and subsequently deducted from the qualifying IP income to ensure a symmetrical treatment of costs and income generated from the intangible assets.

-21.66 percentage points respectively. In addition, the broader scope of Luxembourg's IP box regime compensates the slightly higher IP box rate and provides thus the largest benefit of the considered IP box regimes in comparison to the standard case of the digital transformation. As a result, Luxembourg improves 20 positions in the ranking. In contrast, Luxembourg we observe within the applicable IP box regimes the largest increase in the CoC (+0.2 pp) due to the mandatory capitalization and subsequent depreciation at the lower IP box tax rate (see Appendix 8). While the attractiveness for highly profitable investments increases, marginal ones become less attractive in Luxembourg.

Combining both R&D tax incentive, i.e. input- and output-oriented ones, we observe complementary effects for all IP boxes with the R&D tax credits. The beneficial profit tax rate on IP income compensates the lower tax shield due to an allocation of the costs for the self-developed intangibles and software (except for the UK) against the lower IP box tax rate. Italy still improves its tax location attractiveness with an EATR of -36.66%, followed by Ireland with more than 20 percentage point higher EATR of -6.31% (see Appendix 9). Germany, Japan and the US provide the least attractive location for investments in digital transformation from a tax perspective. While Germany slightly improves its tax burden in compare to the classical manufacturing investment due to favourable provisions for the depreciation of digital investment assets, Japan and the US mostly benefit from their implemented R&D tax incentives.

Figure 10: Difference in effective tax burden measures considering R&D tax incentives and IP boxes



Notes: For the computation of the change in effective tax burden measures, we follow the previous assumptions. In case we do not observe an applicable IP box regime, we use the effective tax burden for a domestic digital investment with (input-oriented) R&D tax incentives.
Source: own illustration and calculation

The more favourable tax base rules for digital business model assets lead to an average EATR of 17.5%. When the R&D incentives are taken into account, the EATR drops further to an average of 9.4%. When the R&D incentives and IP Box schemes are considered together, the average EATR is 8.34%, which is due to the more favourable profit taxes in six of the countries considered.

3.4.3. Sensitivity to varying assumptions for R&D tax incentives

The detailed analysis in the previous chapter illustrates that instruments for R&D promotion strongly affect our results and thus the tax location attractiveness of numerous countries. The substantial reduction of the EATR depends on the particular design of the individual funding instruments. Yet, it can be sensitive to our assumptions made. Up to now we always considered the extreme case, in which we assume that the economic assets at hand fully qualify for R&D tax incentives. To highlight the impact on the effective tax burden through divergent assumptions on the design of specific R&D tax incentives, we provide a detailed analysis of individual fiscal instruments in the following.

3.4.3.1 Accelerated and increased depreciation using the example of Belgium

R&D support instruments that target the tax base depend on the individually applicable tax rate and the profit situation of the company. Thus, companies being subject to a lower tax rate than a competitor are relatively less privileged. In principal, one can distinguish between accelerated depreciation and provisions proving for deduction above the investment volume, i.e. enhanced deductions. Accelerated depreciation of assets results in a shift of expenses over time, from which an interest effect results. Therefore, the effective tax burden decreases in earlier periods before it reverses due to lower depreciation levels in later periods. None of the sample countries specifically uses accelerated depreciation to promote R&D investment. However, in the case of IT investments, which are the focus of the study, accelerated depreciation is used in many countries compared to other movable assets (see Appendix 10), resulting in tax relief. In case of an enhanced deduction, companies deduct a fictitious share of R&D expenses from the tax base over and above their actual expenses, resulting in a permanent reduction of the tax base compared to a pure interest effect due to a shift in time. Again, the sooner a company can claim this enhanced deduction, the more advantageous it is. To illustrate this interest effect in our study, we present the case of the Belgian enhanced deduction in more detail.

In Belgium, a company can choose between a one-shot deduction in the first period, calculated as a percentage of the acquisition value, and a spread deduction over the depreciation period, calculated as a percentage of the annual depreciation amount. The option chosen by the company determines the subsidy rate it faces (one-shot deduction: 13.5%; spread deduction: 20.5%) and thus its effective tax burden. In our study, assuming an real interest rate of 5%, the higher rate for the spread deduction can compensate for the disadvantage of a later claim or, as in the domestic case of digital transformation, even result in a slightly lower EATR (EATR one-shot: 21.16%; EATR spread: 20.49%[56]). Due to the declining-balance depreciation and the associated high depreciation in early periods, the disadvantageous interest effect of the spread deduction is less pronounced. In combination with the assumed return, the interest effect is even negligible. Thus, the higher subsidy rate drives the lower EATR. Alternatively, a company has the option to claim the respective special deduction as a tax credit (one-shot tax credit: 4.6%; spread tax credit: 7.0%). In the event of a loss, any unused tax credit is carried forward and refunded with an effect on liquidity after five years at the latest. In combination with an IP box, the tax credit is more advantageous than the super deduction (see chapter 3.4.3.3).

3.4.3.2 The most popular funding instrument - the tax credit

Most countries implemented a tax credit based on R&D expenditures to promote R&D inputs. When designing a tax credit, one distinguishes between an incremental and volume-based tax credit (see subchapter 3.4.2.2). While volume-based designs benefit all qualifying R&D expenditure, incremental ones only subsidise the increase in R&D expenditure to the reference period. The latter reduces the risk of windfall effects and the fiscal costs (OECD, 2010). Yet, resulting in higher documentation and monitoring for both the company and the tax authorities and a higher risk of a cyclical investment behaviour to benefit from lower average values in the reference period. However, lengthier reference periods minimise this risk.[57] In addition, promoting only the increase in R&D expenditure may result in lower incentive effects for very research-intensive companies that are limited in their expansion by an already very high investment volume.

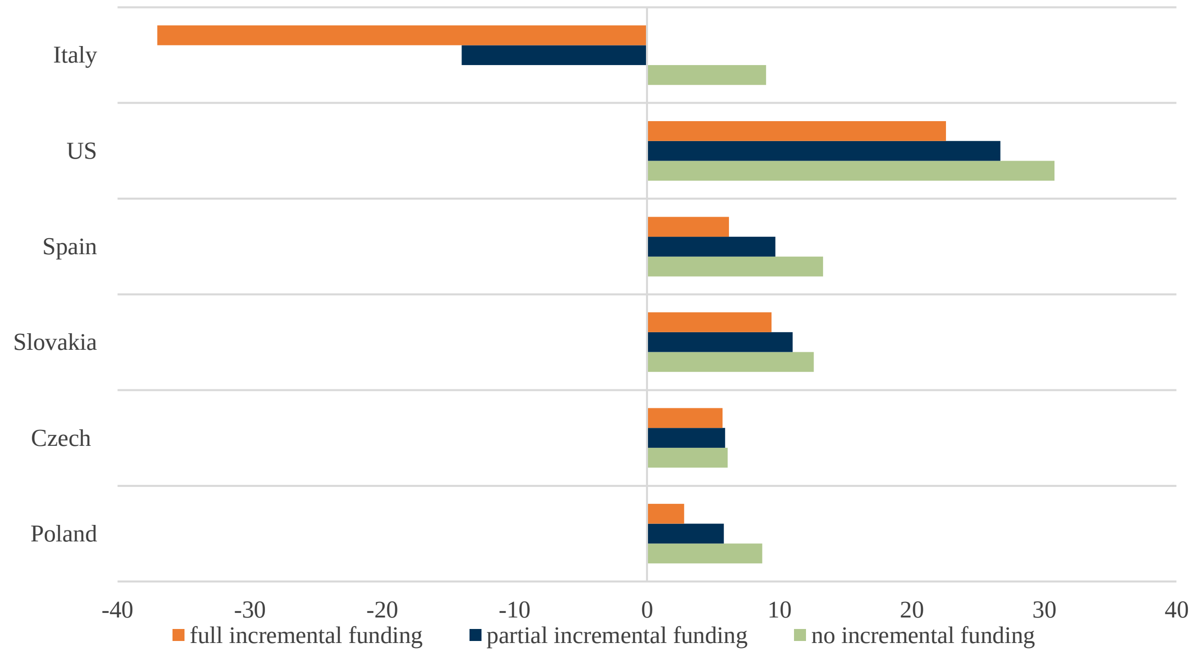
With the combination of a volume-based and incremental tax credit, so-called hybrid regimes, R&D expenditures that do not exceed the thresholds of the reference period are also subsidised. However, it is common for the subsidy rate of the volume-based portion to be lower than that of the incremental one, to incentivise additional R&D investments. Within the group of

[56] This order only results in the case of digital transformation with input-oriented R&D tax incentives. With the consideration of the IP box (as well as a tax credit), the EATR one-time is 13.6% (12.0%) and the EATR spread is 13.8% (12.2%).

[57] The reference period is one year (CZ, SK), two years (ES), or three years (IT with fixed reference period from 2012 to 2014, PL). In Poland, R&D expenditure must also exceed average expenditure by more than 50% to qualify for the increased incremental deduction. In the US, the reference value consists of a fixed percentage (determined from the ratio of R&D expenditure to gross income in a test year) and the average R&D expenditure of the past four years.

countries considered, Italy, Poland, and the USA apply purely incremental tax incentives. While Spain, Slovakia, Portugal and the Czech Republic rely on hybrid tax incentives.[58]

Figure 11: Sensitivity of EATR to different incremental funding rates



Source: own illustration and calculation

Up to now, we assumed that companies can fully benefit from incremental R&D tax incentives.[59] We, thus, implicitly assume that the hypothetical investment is an investment that exceeds the previous average investment. In this way, we take the extreme position that a company continuously expands its annual R&D investment. If, however, a company is not able to expand its R&D investment compared to the respective reference threshold, the effective tax burden corresponds to the tax burden of the domestic baseline scenario, i.e. digital transformation without applicable R&D tax incentives.[60] Besides the two extreme cases, Figure 11 shows the impact of partial incremental support, depending on the shares of eligible R&D expenditure that exceed the threshold. Thus, the resulting EATR is a weighted average of the EATR of an investment without (incremental) tax benefit and an investment with full R&D support.

[58] In Portugal, in addition to the volume-based R&D support considered, an incremental credit is available. However, this is not taken into account, as it is limited in its amount to 1.5 million euros.

[59] With the exception of Poland, as this requires exceeding the reference value by at least 50%. Due to these stricter conditions, only volume-based incentives are considered.

[60] In the case of Italy, for the purposes of the sensitivity analysis, it is assumed that the IP box is applied in the domestic digital transformation case in the absence of incremental support.

Without the incremental tax benefit, we observe significant changes in the country rankings. Italy, this year's leader, drops with an EATR of 9.0% to the 20th rank. A similar picture emerges for Spain, where the EATR rises from 6.2% to 13.3%, resulting in the 23rd rank. Due to the lack of incremental funding, the USA once again is the least attractive location of investments in digital business models from a tax perspective. However, if we assume that 50% of R&D expenditure fall under incremental funding, Italy remains the most tax attractive location. There also slight improvements in the relative tax attractiveness for Spain and Poland.

3.4.3.3 Excessive tendencies with a combination of different funding instruments

In the majority of the countries considered, we observe various R&D tax incentives. In most cases, these consist of a combination of input-oriented R&D tax incentives, i.e., special deduction or tax credit, with an output-oriented incentive, i.e., an IP box. The combination of fiscal instruments can influence the incentive effect differently, as the Italian case shows.

Italy promotes R&D activity with input- and output-oriented fiscal instruments. Besides a reduced corporate income tax rate (13.91 %) through an IP box, it offers a regular R&D tax credit (up to 50 %). In addition, Italy provides targeted incentives for the implementation of the digital transformation of companies through an increased deduction of 140% on investments in the form of software, IT systems and platforms. This deduction is further complemented by a hyper deduction of 250% for smart equipment, i.e. tangible movable assets that are digitally controlled and/or managed like hardware in the context of our study.

Table 6: Combined incentive effect of a super deduction and a tax credit

	Acquired IP	Self-developed IP	Acquired software	Self-developed software	Hardware
Tax credit	50% (180%)	50% (180%)	50% (180%)	50% (180%)	50% (180%)
Super deduction	-	-	140%	-	250%
Total deduction	180%	180%	320%	180%	430%

Source: own calculation and presentation

To illustrate the incentive effect when combining several input-oriented R&D tax incentives, we convert the depreciation allowances together with the special deduction into a tax credit (see Table 6). We observe a converted ‘tax credit’ of 27.81% of the annual expenses, if we multiply the total amount of the deduction by the corporate tax rate. Combined with the regular tax credit, this results in a total subsidy of 77.81% of the annual R&D expenditure. Considering the super- and hyper-deduction increases the combined tax benefit for investment in software and hardware to 88.93% and 119.58% of R&D expenditure, respectively. This already shows the excessive impact of combining several existing tax incentives in our analysis. Table 7 presents the results for the effective tax burden for all combinations of Italian tax incentives.

Table 7: Impact of various Italian R&D support instruments on the EATR

	EATR	CoC
Digital transformation without super deductions and tax incentives	21.4%	5.2%
Input incentive: enhanced deductions		
Super deduction	17.8%	4.2%
Super and hyper deduction	12.9%	2.8%
Input incentive: tax credit		
Tax credit (only)	-24.3%	-7.5%
Input incentives combined		
Super deduction and tax credit	-28.2%	-8.6%
All input incentives	-32.8%	-9.9%
Output incentive: IP box		
IP box (only)	17.5%	5.3%
Input and output incentives combined		
Super deduction and IP box	9.0%	2.9%
Tax credit and IP box	-28.4%	-6.5%
All incentives combined	-37.0%	-8.9%

Source: own calculation and presentation

Especially for IP boxes, both complementary and opposing effects can arise in interaction with input-oriented R&D tax incentives. While the income from the assets brought into the IP box is subject to the lower income tax rate, the reduced income tax rate weakens the effect of special depreciation allowances. Which effect predominates depends on both the amount of the respective special deductions and the spread of tax rates, i.e. regular versus IP box. In our case, the Italian IP box does not negatively affect the value of the special deduction, as it targets self-produced intangible assets and software, which in turn are not affected by the super deductions. The combination of the two support instruments thus significantly reduces the overall tax burden. However, we observe the strongest decline in the effective tax burdens for all cases controlling for the R&D tax credit. The combination with the IP box leads to complementary promotion effects, since its value is unaffected by the tax rate. Digital investments are consistently subsidised by de facto tax benefits, indicated by negative EATRs in all combinations with a 50% tax credit (Evers et al., 2015).

3.4.4. Country Case Studies

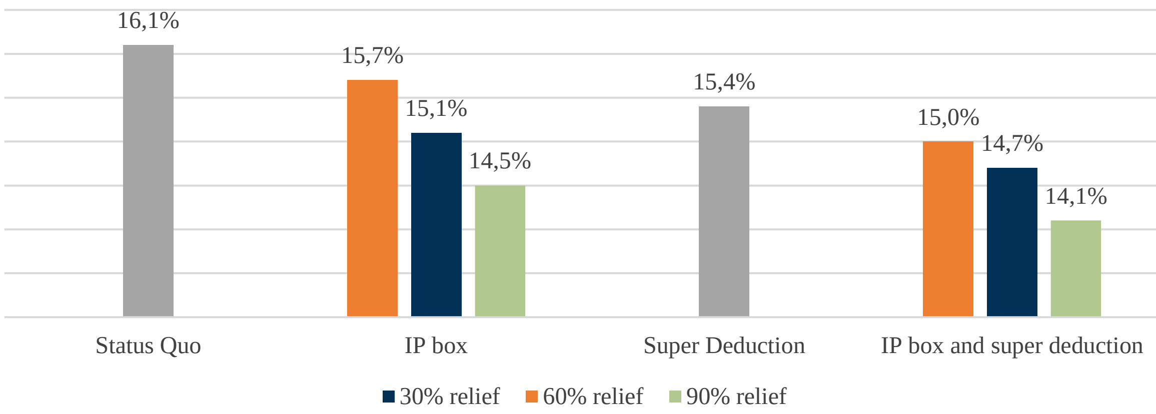
Lastly, we analyse current reform proposals for the introduction of tax incentives for research in Switzerland and Germany which could significantly impact the relative tax location attractiveness of both countries. This is particularly important given Germany's low attractiveness as a tax location for digital business models in the core analysis.

3.4.4.1 *Case Study: Switzerland's reform proposal on R&D tax incentives*

Switzerland considers to introduce several R&D tax incentives to partially compensate the abolishing of tax beneficial treatment of holding companies within the current BEPS discussion. These incentives should help to boost the tax location attractiveness of Swiss cantons. In detail the Steuervorlage 17 (SV 17) considers a mandatory introduction of an IP box at the cantonal level and a voluntary tax base deduction.

With respect to the IP box, the cantons are free to determine the respective relief rate themselves, but the net profit may not be relieved by more than 90%. The planned relief rates range from approximately 30% in Appenzell-Innerrhoden to a maximum relief rate of 90% in Aargau, Basel-Land, Schwyz, Solothurn, Zug and Zurich. According to the current proposal, eligible assets only comprise self-created patents, excluding acquired and self-produced copyright-protected software. However, the scope of eligible income is broader and includes notional royalties from an internal exploitation. The voluntary introduction of an enhanced deduction of up to 50% of R&D personnel expenses (plus a surcharge of 35 % of the personnel expenses)[61] results in an additional deduction of 67.5% (= 0.5*1.35) of the personnel costs.[62]

Figure 12: EATR under the Swiss Tax Bill (Steuervorlage) 17



Notes: Consistent with the core analysis, we assume that the creation of intangible assets and software are current costs in the form of personnel expenses, which qualify for the increased deduction.
Source: own illustration and calculation

The hypothetical case of a sole introduction of the enhanced deduction, leads to the smallest reduction of the EATR (-0.7 pp). The mandatory introduction of the IP box already leads to a

[61] For more details, see Eidgenössiches Finanzdepartment (2017a, 2017b).

[62] In the SV 17, the relief limitation already proposed in the CTR III was adopted, whereby the tax relief may not exceed 70% (formerly 80%) of the taxable profit before relief with IP box, R&D deduction as well as a notional equity deduction. We do not consider this minimum taxation. In the case of an effective minimum taxation at the cantonal level, there is an increase in the EATR.

slightly improvement the tax location attractiveness for Zurich based on the EATR by up to 3 positions. The maximum reduction of 90% of the regular cantonal tax rate, reduces the EATR by 1.6 percentage point to 14.5 %. Due to the complementary effect of the Swiss IP box and the special deduction, the EATR reduces to as low as 14.1%, and thus increases the location attractiveness by 5 positions (rank 23). However, the absence of R&D tax incentives at the federal level moderates the impact of the cantonal fiscal incentives.

3.4.4.2 Case Study: Germany's tax proposals for a R&D tax credit

Germany is one of the few major industrialised nations that have not yet introduced any R&D tax incentives (see Appendix 12). It is, therefore, not surprising that Germany is one of the least attractive tax location for companies with digital business models. For this reason, we show below whether the reform proposals under discussion are sufficient to improve Germany's attractiveness as a tax location for digital business models.

Tax incentives for R&D have been the subject of political discussion in Germany for some time. The coalition agreement of 2009 already discussed the possible introduction of tax-based R&D funding but did not implement it in the following years. Since then, there have been efforts from various political parties, industry and science to push for the introduction of tax-based R&D funding. The high pace of digital change and the associated shortening of innovation cycles force companies to improve their ability to change and innovate. Thus, a fiscal incentive seems timely. Further, the German direct project funding faces criticism that it can only support individual projects and that application-based offering alone can no longer cope with the increasing speed of digitalisation (BDI, 2018). Hence, tax-based R&D funding could be a necessary supplement to the existing project funding due to its administratively easier implementation and its broad impact.

The coalition agreement of the federal government in 2017 sets the goal to create tax incentives, especially for small and medium-sized enterprises (SME) (CDU et al., 2018). Table 8 gives an overview on the various reform proposals for a R&D tax credit. Concerning the scope qualified R&D expenses, the proposals range from all types of R&D expenses, including cooperation projects and contract research, to company's R&D personnel costs only. A restriction to R&D personnel expenses reduces the administrative burden, the potential risk of relabelling and the fiscal costs. Further, it could increase the demand for R&D employees (EFI, 2017). Except for the Bündnis 90/Die Grünen, the funding rate is 10% in all cases. All proposals consider a timely liquidity effect in the form of a tax refund within the corporate income tax (Bündnis 90/Die Grünen, CDU/CSU, SPD, and the German Chemical Industry Association (VCI)) or against the monthly payroll tax (BMWi and the Federation of German Industries (BDI)).[63] A monthly offsetting via the payroll tax would lead to immediate liquidity effects, is independent of the earnings situation of the companies and subject to less fluctuation (EFI, 2017; Spengel, Rammer, et al., 2017).

Table 8: Overview of German proposals for R&D tax incentive

	Type	Target	Scope	Rate	Refund	Allocation basis	Allocation restictions
Bündnis 90/ Die Grünen	Tax credit	SME[1]	All expenses (incl. contract research)	15%	Yes	Corporate tax	Maximum amount € 15 million per company and project
CDU/CSU and SPD	Tax credit	SME[1]	Personnel expenses	10%	Yes	Corporate tax	-
BMWi	Tax credit	SME[2]	Personnel expenses	10%	No	Payroll tax	-
BDI	Tax credit	all	Personnel expenses	10%	No	Payroll tax	capping by setting an eligible salary limit
VCI	Tax credit	all	All expenses (incl. contract research)	10%	Yes	Corporate tax	degressive funding rates

Notes: [1] SME definition according to EU (< 250 employees, annual turnover ≤ 50 Mio. € or annual balance sheet total ≤ 43 Mio. €); [2] SME definition (< 1'000 employees)
Source: own research and presentation

Except for the BDI and VCI, all proposals target SME. Proponents of a restriction to SMEs justify this by the higher risk of financial constraints of SMEs. Yet, one should consider a gradual expansion to large companies after an initial introduction for SMEs (EFI, 2017). In contrast, the VCI proposes degressive subsidy rates according to company size while the BDI proposes a cap on the eligible salary of R&D personal (BDI, 2018). The tax incentive would thus benefit all businesses, with a focus on SMEs.

The scope of eligible R&D expenses mainly drives the impact of a tax credit on company's effective tax burden. To account for the restriction to R&D personnel expenditure, we only consider self-developed intangible goods, including software[64], as eligible expenditures and thus exclude general R&D expenditures, e.g. material costs, investments expenditure. However, even if the legislator chooses a broader tax base, one has to differentiate whether fixed assets, such as hardware or acquired intangibles, are eligible.

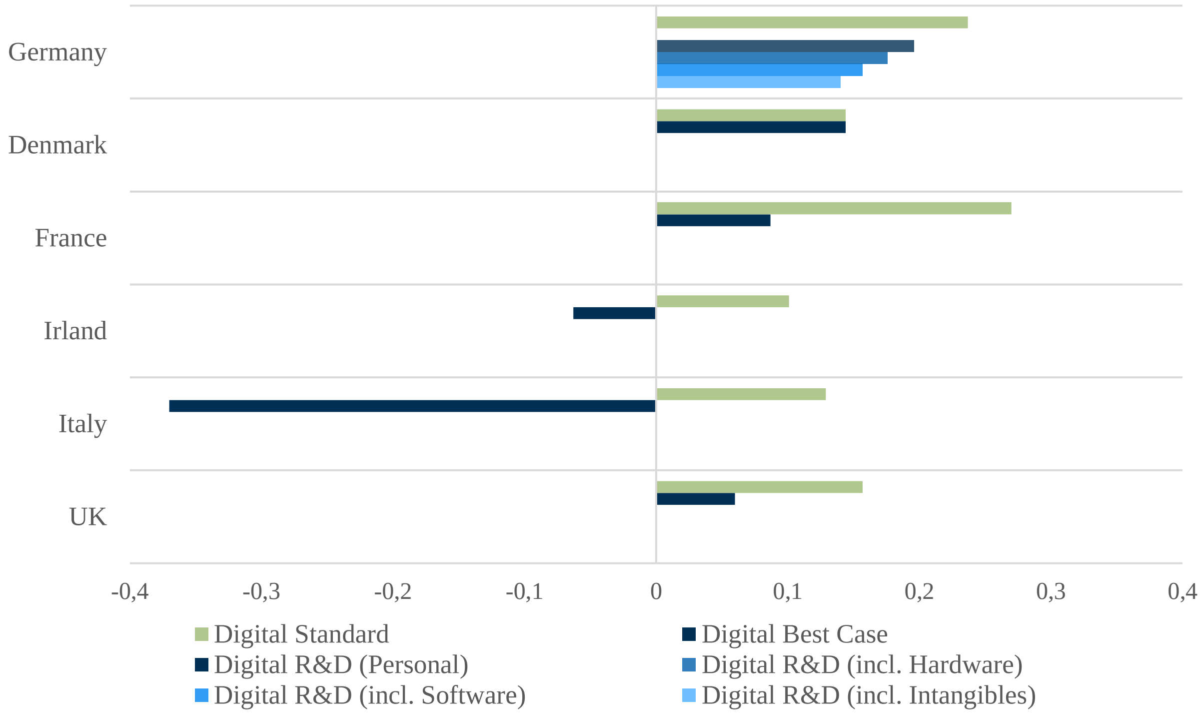
Figure 13 illustrates the impact of different scopes of eligible R&D expenditure on the EATR when considering a 10% tax credit rate for a domestic investment in the digital transformation. To put the impact of a German tax credit in a broader perspective, we consider a representative

[63] An illustration of the German proposals taking into account a loss situation, as is usually observed for start-ups, is not possible within the framework of Devereux-Griffith.

[64] According to the definition of the Frascati Manual 2015, the development of software counts as experimental research (OECD 2015a, p. 65). Here, the assumption is made that scientific or technical progress is achieved.

sample of countries with different tax frameworks and compare the baseline EATR without R&D tax incentives and the best case. However, the discussion of an optimal tax design for R&D support goes beyond this study.

Figure 13: EATR under the German tax proposals with different scopes of eligible income



Notes: For the computation of the effective tax burden measures, we consider a 10% tax credit rate and only vary the scope of eligible expenditure.
Source: own illustration and calculation

The observed reductions range from 4.1 to up to 9 percentage points if one considers the broadest range of eligible expenditures. With an EATR of 14.0%, Germany would improve its relative countries' tax attractiveness by 10 positions. Restricting eligible expenditure to personnel costs results in an EATR of 19.6%. Nevertheless, in an international comparison of the tax attractiveness of locations this does not lead to any improvement, as the high profit tax rate is not sufficiently compensated. Yet, we have to admit that our interpretation of the results is limited, as we do not consider SMEs. To conclusively assess the proposed tax credits and their impact on a countries tax location attractiveness, we would have to consider the perspective of SMEs in an international context as well. Therefore, our quantification serves more as an upper bound of the improvement on location attractiveness as we did not consider more beneficial SMEs' R&D tax incentives of other countries as well. Despite this restriction, Germany does not significantly improve its attractiveness as a tax location for digital business models due to its general high tax environment.

3.5. Conclusion

The digital transformation of the economy with the emergence of new digital business models as well as the increasing transformation of existing non-digital business models is progressing continuously. These trends intensify competition not only among industries but also among governments to become an investment location for these innovative businesses. Especially, the lean corporate structure of digital businesses and their ability to serve international markets without a significant physical presence enables the high mobility of core activities and the location of key assets and resources. The decision to create a nexus in a specific country can therefore be crucially dependent on the overall tax environment given that taxes are an important cost factor.

Our qualitative research highlights that the relevant tax parameters for investments in digital business models vary to a large extent across countries. Thus, it is not surprising that we observe large differences in the effective tax burden with digital business models with a spread of more than 55 percentage points between the most attractive location in Italy and the least attractive in Germany in 2017. In principle, the effective tax burden for investments in digital business models is on average lower than for traditional business models, which is also reflected in lower capital costs. Yet, we already find that the effective tax burden is on average four percentage points lower in comparison to traditional business models even before considering any special tax incentives. The relevant driver is the higher share of current costs and their immediate tax deductibility as well as accelerated depreciation for IT assets.

The core activities of digital business models with a focus on the development of new software facilitate the applicability of R&D tax incentives and IP box regimes for the majority of countries considered. Our overall index as well as the sensitivity analysis show that instruments for R&D promotion strongly influence the effective tax burden measures and thus the tax location attractiveness of numerous countries. However, the strong reductions in the effective tax burden are dependent on the concrete design of the individual funding instruments. Especially among the widespread input-oriented R&D tax incentives, we observe several countries which heavily subsidize the investments in digital business models, as indicated by the negative effective tax burdens. This strong tax-reducing effect of R&D tax incentives is further amplified due to the large share of current expenses. In contrast, for IP box regimes both complementary and opposing effects can arise in interaction with fiscal instruments that are applied on the input side.

However, our study results clearly show that countries that have no or only moderate fiscal R&D instruments clearly fall behind in their location attractiveness. This becomes particularly evident for locations that are already characterised by a comparatively high tax environment, such as Japan, the US, Germany and Switzerland. Especially, for the latter ones, we show that the planned introduction of R&D tax incentives does not compensate for the fiscally unfavourable high corporate income tax rates and tax base provisions.

Considering that investments in the digital economy and digital business models are strongly linked to economic growth and increased productivity, country's innovation policies, including taxation, should be thoroughly evaluated. In extreme cases the effective tax burden of digital companies in neighbouring industrial nations differs by over 30 percentage points, which could lead to significant distortions in the optimal capital allocation. The study thus provides new insights into the assessment of entrepreneurial decisions and suggests tax policy options with regard to the investment activities of companies with digital business models. In particular, when corporate decision-makers take into account statutory tax rates, depreciation rates for IT assets and special incentives (R&D schemes and IP boxes), taxation becomes an important policy element to attract mobile activities, digital infrastructure and assets as well as human capital into the digital economy.

4. R&D Tax Incentive Regimes – A Comparison and Evaluation of Current Country Practices[65]

4.1. Introduction

Innovation is considered the prerequisite for economic growth, global competitiveness, and social welfare. Empirical research finds that increasing R&D activities by 1% of GDP increase economic growth by 0.32% to 1.18% (Akcali & Sismanoglu, 2015). The importance of innovative activities is accentuated during an economic crisis, as persistent R&D performers seem to survive crisis better than their competitors. In that sense, high R&D intensity acts as a form of insurance against future economic downturns (Lome et al., 2016). Furthermore, investments by businesses in R&D are pro-cyclical on aggregate, and thus, apt to contracting in crisis (OECD, 2021b). Therefore, it is of primary importance for governments to provide a nourishing environment to R&D performing firms not only in general, but also in crisis times. Even more so, in a recently slowing economy and with the need for digital transformation. As investing in innovations is costly, the benefits of research highly uncertain, and public spill overs greater than private ones, the private sector does not undertake the optimal amount of R&D activities. Thus, governments must correct this market failure. There are several ways to foster private R&D. In the last decade, the most prominent tools are direct grants and tax incentives.

Tax incentives are especially attractive to spur R&D activity. One reason for that is that they reduce the cost of development,[66] and, therefore, positively impact the risk-return profile of R&D activities. They are also neutral towards the kind of R&D being carried out, which can make them more attractive than direct grants. Furthermore, in the context of cross-border tax competition, R&D tax incentives can be used as a tool to enhance investment attractiveness.

This paper evaluates both, qualitatively and quantitatively, the current R&D tax incentive regimes in place in ten important FDI countries (Belgium, Germany, Spain, France, Ireland, Netherlands, United Kingdom, Switzerland, China, and the United States) considering effects on location attractiveness, innovative activity, and profit shifting. First, we describe and analyse the different design features of the existing R&D tax incentives in our sample countries. Second, we use forward-looking effective average tax rates (EATR) to measure the effect of

[65] This chapter is joint work with Christoph Spengel and Barbara Stage. We gratefully acknowledge support from the MannheimTaxation Science Campus, funded by the Leibniz Association, the state of Baden-Württemberg, and the participating institutions ZEW and University of Mannheim.

[66] Businesses that take advantage of these incentives will be able to reduce the cost of research or drive more innovation at the same cost.

R&D tax incentives on location attractiveness quantitatively. We base the computation of the effective tax burden on the well-established methodology of Devereux and Griffith (1999, 2003). Using the extension of their model by Evers et al. (2015), we compare the effective tax burden of an investment in a patent with and without R&D tax incentives. With this, we deliver novel evidence on the effect of the current R&D tax incentives in place as of 2020 on location attractiveness, especially regarding the location of R&D activities.[67]

EATRs are preferable in an analysis of locational tax attractiveness over statutory corporate tax rates, since they incorporate additional aspects of a tax system, such as tax allowances, local profit tax rates, surcharges, non-income tax charges, as well as tax incentives. Also, EATRs are especially well suited to point out the relative importance of R&D tax incentives such as R&D tax credits or deductions. Our EATRs can thus be viewed as a summary measure to facilitate a comprehensive analysis of the effect of R&D tax incentives on tax location attractiveness. Last, we discuss our results more broadly in light of the related empirical evidence. In this final discussion, we evaluate the current R&D tax incentive regimes with regard to effects on innovation, tax competition, and profit shifting.

A study on R&D tax incentives effect on location attractiveness is timely and relevant. The choice of instruments we observe underlines that R&D tax incentives are not only used to incentivize R&D investments but often with the primary goal to increase location attractiveness, sometimes increasing profit-shifting opportunities. Firms can choose where to locate their business activities in a cost-minimizing way, and it is well established that taxes play a non-negligible role in these location decisions.[68] R&D investments heavily involve intangibles, which multinationals may shift more easily among subsidiaries than other asset classes. The mobility of intangibles, in principle, allows that multinationals deduct development costs in a high-tax jurisdiction and locate the intellectual property in a country with a lower tax rate. Therefore, out of all R&D tax incentives, international organizations such as the OECD criticized so-called IP box regimes. The critique is based on a mismatch between tax reduction and the place of economic activity: IP boxes allow profits from intellectual property (IP) to be taxed at a low or even zero corporate income tax rate without providing a clear link with the location of R&D activity. Thus, the intent of IP box regimes does not seem to be, exclusively, the fostering of new R&D activity, but instead the attraction of IP-revenue from abroad. As a consequence, the OECD's Base Erosion and Profit Shifting (BEPS) Report (see OECD,

[67] For a detailed EATR-based analysis of the tax attractiveness of countries for investments in digital business models, see Spengel et al. (2018) and Olbert et al. (2019).

[68] For a review of the literature, see De Mooij and Ederveen (2008), Devereux and Maffini (2007).

2015b)) declared certain existing specific tax regimes, among them IP boxes without a substantial activity requirement, as harmful tax practices.

Due to this increased scrutiny on special tax regimes, countries interested in maintaining or improving their competitive position are now more constrained. Simultaneously, the environment of offered R&D tax incentives has been highly dynamic in very recent years, potentially, because (other) tax competitive instruments have been under the eye of the OECD BEPS Project.[69] Several R&D tax regimes have been newly implemented or substantially overhauled. For these reasons, we believe that a detailed comparative evaluation of current R&D tax regimes as of 2020, primarily focusing on tax competition effects, is relevant to both policymakers and researchers.

This analysis proceeds as follows: In chapter 4.2, we first give an overview of possible instruments in the area of R&D tax incentives based on which we lay out the role of R&D tax incentives in incentivizing investments in research and development and in increasing the location attractiveness of countries. In chapter 4.3, we describe and compare the R&D tax incentives in the ten investigated FDI-countries. In chapter 4.4 follows the quantitative evaluation of the effect of the R&D regimes on location attractiveness. First, we introduce the Devereux-Griffith methodology and the parameter assumptions made for the following qualitative analysis. Second, based on forward-looking effective tax rates, we evaluate the R&D tax incentives' effects on investment. In chapter 4.5, we discuss our findings in light of the empirical literature. Finally, we conclude in chapter 4.6 that R&D tax regimes continue to play an essential role for FDI attractive countries and are likely to do so in the future.

4.2. Overview of R&D tax incentive instruments

The usage of R&D tax incentives to encourage private R&D investment is not a new phenomenon. Governments rely on specific tax rules for the promotion of R&D since the 1970s when Ireland began exempting patent income. The United States joined later with an R&D tax credit in 1981, and France's research tax credit has been in place since 1983. Justifications given by governments for the introduction of an R&D tax incentive during the last decades could be summarized as follows: First, governments want to support their economy in the transformation process to a knowledge-based economy. Therefore, they encourage new potential entrepreneurs to undertake R&D activity to create high-quality jobs in innovative

[69] It is not surprising to observe an increased usage of R&D tax incentives as of 2016 as the legitimization of IP boxes fulfilling the Modified Nexus Approach highlighted the importance of R&D tax incentives as a promising instrument to take part in the global tax competition.

sectors. Second, governments try to retain or increase their attractiveness to domestic and foreign entrepreneurs conducting R&D activity.

Based on the overall aim and the phase of the research process to which R&D tax incentives apply, one can classify the different tax instruments as input-oriented or output-oriented incentives. The majority of costs arise during a research project's input phase as firms plan and conduct research (Arginelli, 2015). R&D tax incentives that apply to this phase of the research process aim to stimulate additional R&D by alleviating a company's financial burden as R&D expenses occur but income is uncertain and yet to be generated. These tax incentives aim to reduce the cost of conducting R&D by providing a direct link between R&D expenditure (e.g., capital investment, current, and personnel expenses) and the tax benefit generated. The design of such input-oriented tax incentives varies: Some of the support measures aim to reduce a firm's tax liability, while others target its tax base. The first category includes R&D tax credits, which constitute a direct offset against the company's tax liability. The second group comprises tax super-deductions and accelerated depreciation of assets used in R&D, which provide for incremental tax base reductions.

Besides differentiation along these general types, input-oriented R&D tax incentives can have several design features. The most important determinants of the generosity are: the scope of the support measures (e.g., incremental or volume-based), the eligible R&D expenditures (e.g., internal or external expenses in nature of capital, current or personnel expenses), selectivity in the circle of eligible companies (e.g., all taxpayers, specific company sizes, ages, sectors or technologies), refund possibilities, and carry-forward provisions, as well as the tax base against the benefit is credited. Furthermore, some governments limit the amount of tax incentives receivable by companies to reduce tax revenue loss (e.g., in terms of the total amount of support received or percentage of tax due).

After successful research the output phase begins, in which the company exploits the returns of the created intangible asset. The second type of R&D tax incentives, notable, IP boxes, targets these returns by taxing them at a reduced tax rate. With this output-oriented instrument, governments do not directly favour the establishment but the exploitation of R&D as only successful innovations benefit. As already stated, IP boxes date back to the 1970s in Ireland. Since then, a couple of countries joined the club that offers regimes to decrease the corporate tax rate on intellectual income. In the early 2000s, IP boxes became a European phenomenon. These instruments were special because they did not necessarily require a nexus between the tax benefit and R&D activities within one country. As Evers et al. (2015) showed, these early

IP box regimes significantly reduced the effective average tax burden on patent investments.[70] Due to the missing nexus, opponents of IP box regimes stated that these instruments are harmful as they increase tax competition without providing any evidence of increased R&D activity (Theophilou, 2019). With increasing criticism and the beginning of the BEPS project in 2015, the IP box trend came to a temporary stop. However, since the OECD legitimatized IP boxes if they satisfy a ”substantial activity requirement”, several countries implemented IP boxes or continued existing regimes after adaption to the OECD-conform so-called Modified Nexus Approach (see OECD, 2015b)). The OECDs' Modified Nexus Approach, in principle, shall only allow a taxpayer to benefit from a IP box regime to the extent that it can show that it incurred R&D expenditures, which gave rise to the patent income and shall in-so-far limit cross-border profit shifting with regard to IP box income. Meanwhile, IP boxes are not only a European but also a global phenomenon. Eight countries evaluated in this study (see Table 10) make use of an IP box regime.

4.3. Overview of relevant country practices

The existing R&D tax incentives schemes differ significantly across countries regarding their generosity, design, and which firms or specific areas they target. Therefore, we first qualitatively analyse the respective incentive schemes in our comparison countries. We consider all R&D tax incentives, which are available for manufacturing companies. Incentives, which specifically target only SMEs, special investment categories (e.g., environmental friendly technologies), young companies, companies with a strong growth rate, a particular ownership structure, or within a specific region, are not included in the analysis. Some regimes also limit the absolute level of usable incentives by setting a nominal cap on the resulting tax benefit or require that costs exceed a certain reference value in order to be considered for expenditure-based incentives. Since these schemes are usually generous in scope, allowing many companies to benefit from them, the corresponding incentives are implemented in the model. We refer to tax regulations effective as of 2020.[71]

[70] For a comprehensive overview on design features of European IP boxes and their impact on the effective average tax rate, see Evers et al. (2015).

[71] The information on relevant tax parameters of R&D tax incentives presented in this study is mainly based on the following sources: EY (2020b), IBFD (2020) and PwC (2020). Belgium: Delanoy et al. (2020); France: Silberztein and Bricard (2019), Council of the European Union (2019a); Ireland: Flanagan (2016), Revenue Irish Tax and Customs (2020a, 2020b). Switzerland: Hausmann et al. (2016), Hausmann (2018), Eidgenössisches Finanzdepartment EFD (2020), BDO Schweiz (2020), Statistisches Amt Zürich (2020).

4.3.1. Input-oriented measures

The comparison group comprises all classical input-oriented R&D tax incentive instruments for capitalized assets (e.g., machinery and buildings), including accelerated depreciation, super deductions (under which, instead of the actual expenditure, an exceeding amount is recognized), and tax credits. With regard to current expenses, we observe super deductions and tax credits. Table 9 provides an overview of the main characteristics of these input-oriented R&D tax incentives.[72]

Five countries offer accelerated depreciation for assets subject to mandatory capitalization if used for R&D (e.g., machinery and buildings). Except for Belgium, all five of these countries allow an immediate write-off of machinery used for research activities. In Ireland and the United Kingdom, the full write-off comprises even R&D buildings, whereas Spain significantly reduces the depreciation period of R&D buildings from 35 to 10 years. These instruments only lead to a shifting of R&D investment expenditure forward in time and, thus, interest rate effects.

Yet, all countries under study offer further incentives in the form of super deductions on the tax base or tax credits on the tax due that reduce the tax base beyond a timing effect. The majority of countries relies on R&D tax credits (Belgium, France, Germany, Ireland, Spain, UK, and the US). China makes use of a super deduction, which implies that the effective incentive rate is the product of the applicable corporate income tax rate and the enhanced deduction. Overall, our qualitative analysis yields an extensive range of incentive rates across the countries considered, with the lowest headline rate of 12% in the United Kingdom and the highest tax credit rate of 42% in Spain.

Spain restricts the eligibility to current expenses as well as machinery and equipment. Belgium is a special case in our comparison group as it limits the general tax credit to capital investment expenditures. However, certain personnel expenses are eligible for a wage tax reduction for R&D personnel. Furthermore, the observed R&D tax incentives differ with regard to the tax type they can be credited against. The Netherlands' tax credit and the reduced wage tax in Belgium for R&D employees are the only instances in our sample in which the incentive is credited against payroll taxes instead of the corporate income tax, leading to a faster liquidity effect as the payroll withholding tax is a monthly tax compared to the annual corporate income tax.

[72] In our qualitative and quantitative analysis we only consider the federal R&D tax incentive for the United States. Further, we restrict our analysis to the R&D tax incentive applicable in the Swiss canton Zurich.

Table 9: Input-oriented R&D tax incentives in place in 2020

Country	CIT	Input oriented R&D tax incentives								Accelerated depreciation	
		Type of instrument	**Base**	**Eligible expenditure**	**Headline rates (%)**	**Credited against**	**Refund**	**Carry-over**	**Ceiling**	**Eligible expenditure**	**Headline rates (%)**
Belgium	29.6	super deduction (or tax credit [f]	volume	M / B	13.5 (one-shot)	CIT	after 5 years (tax credit)	indefinitely	.	M	33.33 (SL)
		wage tax reduction	volume	C [e]	80%	payroll WHT	.	.	.	.	.
China	25	super deduction	volume	C / M / B	175	CIT	.	5 years	.	M / B	DDB or reduction of depreciation period by 40%
France	35.4	tax credit	volume	C / M / B	30 / 5 (> EUR 100’000’000)	CIT	after 3 years	3 years	.	.	.
Germany	30.5	tax credit	volume	C	25 (< EUR 2’000’000)	CIT	yes	.	EUR 1’000'000	M	100
Ireland	12.5	tax credit	volume	C / M / B	25	CIT	yes	indefinitely	.	M / B	100 / 100
Netherlands	25	tax credit	volume	C / M / B	32 / 16 (> EUR 350'000)	payroll WHT	.	1 year	.	.	.
Switzerland (Zurich)	21.15	super deduction	volume	C [d]	50	CIT	.	.	.	.	.
Spain [a]	30.6	tax credit	hybrid	C / M	59 / 33	CIT	partly	18 years	25% of gross tax liability [c]	M / B	100 / 10 (SL)
UK	19	tax credit	volume	C	12	CIT	yes	indefinitely	.	M / B	100 / 100
US (California)	27.98	tax credit	incremental	C	20 [b]	CIT	.	1 (back), 20 years	25% of tax liability	.	.

Abbreviations: C=current expenses (e.g., wages, material, etc.), M=machinery/equipment used for R&D, B=industrial buildings used for R&D

Notes: [a] In the model the incremental component (42%) is considered. Furthermore, additional tax credits available for R&D staff expenses (17%) and tangible assets (25% + 8%) exclusively used for R&D activity are considered. [b] Taxpayers who elect to claim the R&D tax credit have to reduce the business deduction for R&D expenditures or they take a reduced tax credit that equals the gross credit multiplied by (1-CIT rate). [c] If the amount of qualified R&D expenses for the tax year exceeds 10% of the tax due (after reducing for tax credits), the tax credits may not offset greater than 50% of the gross tax due. If the amount of R&D expenses does not exceed 10% of the tax due (after reducing for tax credits), the credits may offset up to 25% of the gross tax due. [d] Only payroll costs are allowed, all other current expenses are considered by increasing the deduction by 35% of payroll costs. [e] In Belgium only personnel expenses are eligible as current expenses. [f] The rate of the tax credit is defined as CIT*13.5%.

As liquidity is often a significant obstacle for young and small firms to innovate, best-practice nowadays is the inclusion of a refund option for R&D tax credits for tax-exhausted companies. Germany, Ireland, and the UK, which especially try to target SMEs,[73] have schemes that offer an immediate cash refund. The US's carry-back option can have a comparable effect as a direct cash refund if the company had a positive tax liability in the previous year. All other countries provide carry-forward options of excess tax credits with a broad variety of years allowed ranging from one year to infinity.

In principle, tax incentives for R&D can apply to all taxpayers, or they can be selective. Even though we focus on R&D tax incentives that ex-ante apply to all taxpayers, we observe differentiating features in the tax regimes that we study that target specific groups (e.g., SMEs). Instead of restricting the eligibility to the size of a company, the support is limited in terms of the amount of R&D tax incentive received (e.g., as observed in Germany) or by a regressive incentive rate with increasing R&D expenditures (e.g., as in France and the Netherlands). To limit the government's revenue cost, Spain and the US apply a ceiling to the R&D tax benefit granted to the individual company (based on a pre-defined percentage of the corporate tax due).

4.3.2. Output-oriented measures

Besides often used input-oriented R&D tax incentives, countries rely more and more on output-oriented instruments to provide incentives on the exploitation of intellectual property within the country. Out of 10 countries analysed, only Germany, China[74] and the United States do not use this instrument (see Table 10). The most prominent feature of IP boxes is the tax rate applicable to the IP income, which ranges from 4.44% in Belgium to 15.93% in Spain. The other key features that determine the generosity of this instrument are (i) the scope of qualifying assets, (ii) the scope of qualifying income, and (iii) the treatment of expenses relating to qualifying IP income.

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[73] These schemes target SMEs by applying higher incentive rates to SMEs or an absolute ceiling of the amount of benefit received.

[74] The Chinese High and New-Technology Enterprise (HTNE) program, in place since 2008, reduces the corporate income tax rate by 10 percentage points to 15% on profits of intellectual property rich companies. In contrast to existing European IP boxes the HTNE program links the eligibility not to IP assets themselves, rather it focuses on what the company is actually doing in China in terms of R&D investment and employment (EY, 2020b). Thus, we do not consider the incentive in the following analysis as it does not constitute an IP box in the strict sense.

The introduction of the Modified Nexus Approach streamlined the scope of eligible intellectual property assets. Generally, marketing intangibles (e.g., trademarks, brands, know how) are not eligible anymore (OECD, 2015b). Nevertheless, the range of qualifying assets is relatively broad, as it comprises, among others, patents, supplementary protection rights, copyrights to software and computer programs, plant breeder's rights, orphan drugs, utility models, and market exclusivity regarding medicinal or veterinary products. Compared to the situation before 2016, some countries (e.g., Spain and Belgium) nowadays have a broader range of qualifying assets than before (including utility models, supplementary protection certificates relating to drugs or plant-protection products, as well as advanced software).

Table 10: IP box regimes in place in 2020

	Date of implementation / BEPS compliant since	IP box rate (%)	Main rate[a] (%)	IP box tax base	
				Treatment of current expenses	Treatment of R&D expenses incurred in the past
Belgium	2007 / 2016	4.44	29.58	Net income	Recapture
China	.	.	25	.	.
France	2000 / 2019	11.68	35.41	Net income	Recapture
Germany	.	.	30.53	.	.
Ireland	2015/ 2016	6,25	12,5	Net income	No recapture
Netherlands	2007 / 2017	7	25	Net income	Recapture
Switzerland (Zurich)	2020	9.36	21.15	Net income	Recapture
Spain	2008 / 2018	15.925	30.625	Net income	Recapture
United Kingdom	2013 / 2016	10	19	Net income	Recapture
US (California)	.	.	32.551	.	.

Notes: [a] The main rate presented includes the corporate income tax rate and, if applicable, surcharges (Belgium, France), local income taxes (Spain) and other income taxes (France). We generally apply the maximum rate.

Strongly related to the qualifying assets is the determination of qualifying IP income. All comparison countries allow royalty income. However, only some countries (e.g., Belgium, Ireland, Netherlands, Switzerland, and the UK) consider embedded royalties as qualifying income, allowing companies to consider income from the sale of products or services incorporating the patented invention or process. This is especially relevant for the manufacturing and services sector (HM Revenue & Customs, 2020). Except for Ireland, all other countries also include capital gains from the disposal of qualifying IP (or the underlying intangible asset). Belgium requires that the sale proceeds are reinvested in qualifying IP expenditures within five years.

Besides the tax rate, another major determinant of IP box regimes' generosity is the treatment of expenses relating to qualifying income. Before implementing the Modified Nexus Approach in OECD countries, there were different treatments concerning current expenses incurred in the development phase (Evers et al., 2015). In the gross approach, R&D expenses are deductible against the regular higher corporate income tax rate. Thus, they created a tax shield. In the net approach, R&D expenditure has to be attributed to and deducted against IP box income. As a result, it is deducted at the lower IP box rate. The comparison group only includes countries compliant with the OECD's Modified Nexus Approach, under which the application of the net approach is mandatory. The existing IP boxes still differ, however, with regard to the treatment of past R&D expenses. If the IP box regime does not require to offset the original deduction of expenses at the higher corporate income tax rate, so-called recapture, this results in a very generous tax treatment. In our sample, only the Irish IP box regime does not recapture previously deducted R&D expenses before income is eligible to the IP box (in contrast, Evers et al. (2015) still found that most IP boxes did not have a recapture mechanism in place).[75] All other countries in our sample, except for Belgium and Switzerland, apply the IP box rate only to IP income exceeding the initial R&D expenses. Belgium offers firms two options: either they opt to fully deduct initial R&D expenses in the first year of the IP box usage or, by capitalization of R&D expenses, to spread the deduction over a maximum of seven taxable periods. In Switzerland the IP box also prescribes capitalization of R&D expenses and consecutive write-off from the moment the firm opts to enter the IP box regime. Capitalization is usually less beneficial for taxpayers.

To conclude, both types of R&D tax incentives, input- and output-oriented incentives, offer the potential to reduce the effective tax burden of innovating companies on their own. However, within our comparison group, all countries allow the simultaneous use of both R&D tax incentive regimes, which can significantly increase the incentive effect by reducing the effective tax burden on R&D investments even further (see the quantitative analysis below).

4.4. Quantitative evaluation of R&D tax incentives' effects on location attractiveness

4.4.1. Methodology for the analysis

In modelling the impact of R&D tax incentives on firms' effective tax burdens, we follow the methodology put forward by Devereux and Griffith (1999, 2003), which builds on the work of Jorgenson (1963), Hall and Jorgenson (1967) and King and Fullerton (1984).[76] This neoclassical approach assumes that firms invest in capital as long as marginal returns cover marginal costs. Therefore, investment takes place until the return is equal to the cost of capital

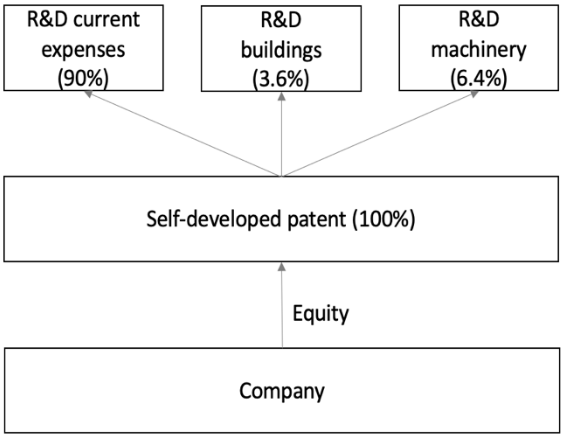
[75] In the past, Spain did not require a recapture of R&D expenditures (Evers et al., 2015). However, we assume that the current regime applies a recapture as the relief is based on income which is defined as the positive difference between revenues derived from the assignment of the right of us or exploitation of intangibles and amortization, impairments as well as expenses directly linked to the assigned asset that have been included in the CIT taxable base (EY, 2020b).

[76] It is regularly applied to compute the effective tax burden for investments in the manufacturing industry in studies regularly conducted by the ZEW for the European Commission, see Spengel et al. (2021).

– the minimum pre-tax real rate of return required by an investor given a post-tax real rate of return on an alternative (financial) investment. In line with neoclassical investment theory, this approach rests on the assumption of a perfect capital market under certainty.

The approach of Devereux and Griffith (2003) allows the evaluation of the tax environment to go beyond statutory tax rates, as it incorporates further significant features of the underlying corporate tax system, e.g., tax bases, local profit tax rates, non-income tax charges, as well as tax incentives (Jorgenson, 1963; King & Fullerton, 1984).[77] Especially, in the context of R&D tax incentives this framework allows us to account for the different scope of R&D tax incentive bases (i.e., current and capital expenditures) or different design features of the patent box (see below). Therefore, their approach can more comprehensively point out distortions of taxes on investment decisions and highlight possible effects of tax incentives (Devereux & Griffith, 2003).

Figure 14: Investment structure of the self-developed patent



Source: own illustration

Furthermore, this approach enables us to compute effective tax burdens not only on investments that just yield their cost of capital but also on profitable ones (EATR). The cost of capital indicates the return a marginal investment must realize before tax in order to be worthwhile for the investor. In contrast, the EATR measures the change in the net present value (NPV) of a highly profitable investment caused by taxation $(R^* - R)$[78] relative to the discounted pre-tax rate of return (p):

$$EATR = \frac{R^* - R}{\frac{p}{1-r}} \tag{8}$$

[77] For an overview of the tax parameters considered in each sample country, see Appendices 14 and 15.

[78] The NPV before taxes (R^*) equals the economic rent of the investment and is defined as: $R^* = \frac{p-r}{1+r}$.

The EATR is especially relevant when companies decide on the geo-graphical allocation of economic returns in investment location decisions. From a set of discrete, mutually exclusive investments with an identical pre-tax real rate of return, the investor will choose the location for which the net present value is least reduced by taxation. That is where the EATR is lowest (Schreiber et al., 2002). Therefore, the EATR is the relevant measure in our study, as we analyse the effect of corporate taxes on multinational firms' choice whether or not to choose a specific country as an investment location for a given R&D activity: The lower the EATR, the more attractive the location for R&D activities from a tax perspective.

Our analysis is an adaptation of the Devereux-Griffith methodology to the case of an R&D investment. The standard model refers to a manufacturing company that invests in five different assets: machinery, industrial buildings, inventory, financial assets, and acquired patents. Furthermore, it differentiates between three ways of financing: retained earnings, new equity, and debt (Devereux & Griffith, 1999, 2003; Schreiber et al., 2002; Spengel, 2003). To highlight the impact of R&D tax incentives, we follow Evers et al. (2015) and focus on a hypothetical investment in an equity-financed self-developed patent. We model a self-developed intangible asset, because the intention of tax incentives for R&D activity is to favour innovations created in the company, often legally protected in the form of patents. To incorporate the effect of various R&D tax incentives, we expand on the baseline scenario of Evers et al. (2015) as we assume that the company has not only current expenses (e.g., wages for R&D staff and materials) but also invests in an R&D infrastructure (e.g., buildings and machinery). However, we still assume that current expenses account for the largest share of R&D expenditures (90%) (Bloom et al., 2002; Cameron, 1996; Dougherty et al., 2007; Evers et al., 2015; B. H. Hall, 1995), while only 3.6% of the investment is in R&D buildings and 6.4% in R&D machinery (Bloom et al., 2002; following Evers et al., 2015).

Assuming a common asset mix across all locations we study not only allows us to compare our results between the locations we study and with the existing literature it also reflects the average R&D expenditure of the countries considered (see Appendix 16). We show the low sensitivity of our findings to choosing a country specific asset mix. Furthermore, we show sensitivity of our findings to debt financing of the investment.

The calculation of the NPV after taxes (R) is in the core of our analysis. In general, it is defined as[79]:

[79] For an investment financed by debt, one has to add a financing term. Further, in Belgium one has to adjust for the notional interest rate deduction. For more details on the methodology, see Spengel et al. (2021).

$$R = -(1-A) + (1-\tau)\frac{(p+\delta)(1+\pi)}{1+i} + (1-A)\frac{(1-\delta)(1+\pi)}{1+i} \quad (9)$$

where A denotes the NPV of tax allowances, τ the applicable corporate income tax rate, p the pre-tax rate of return, δ the economic depreciation rate, π the inflation rate and i the nominal interest rate.[80] In the following, we lay out how we adjust A in our calculations of EATRs to account for input-oriented R&D tax incentives as well as patent-box-specific regulations.

Generally, current expenses from the creation of a self-developed intangible asset are deducted immediately from taxable income. This implies that the NPV of tax allowances related to current expenses (denoted by A) is given by the applicable tax rate τ. Resulting in $A = \tau$ (Evers et al., 2015). In case of a super deduction of current expenses, the expenses are recognized at an amount higher than the actual expenses, thus reducing profits. For this purpose, they are multiplied by a factor of $1 + \gamma$, where γ is the amount of the additional deduction. The amount of relief, therefore, increases to $A = \tau * (1 + \gamma)$. In contrast, tax credits are defined as a proportion $\emptyset$ of the expenses and are deducted directly from the tax liability. They are, therefore, independent of the applicable tax rate and directly increase the relief amount $A = \tau + \emptyset$.

To account for IP boxes, we replace the regular corporate income tax rate τ by the effective patent box rate τ_{IP}. Further, to incorporate the effect of the recapture mechanisms of existing patent boxes, we assume that the model firm incurred current expenses before patent box election.[81] From this follows that, when we model a patent box with a recapture mechanism, the applicable tax rate for deduction of current expenses corresponds to the patent box tax rate τ_{IP}. If we implement a patent box without a recapture mechanism, the regular corporate income tax rate is decisive (this is only the case in Ireland). While we account for the recapture of R&D expenses by applying the lower patent box rate, we abstract from depreciation if the patent box expenditures are to be capitalized (which is the case in Switzerland and optional in Belgium).[82] In modelling the interaction of input- and output-oriented tax incentives, we

[80] We make the following parameter assumptions (Table 11): the capital market real interest rate is 2 percent; the inflation rate is 0.73 percent; the pre-tax rate of return is 20 percent; the economic depreciation rate for a self-developed patent is 15.35 percent, for machinery 17.5 percent and for buildings 3.1 percent. The real interest and inflation rate is based on cross-country average values in 2015 (Hanappi, 2018)

[81] The assumption that current expenses are incurred prior to IP box election is realistic, when we consider that patents are the outcome of past R&D activity. As Evers et al. (2015), we abstract from expenses incurred in the on-going IP management.

[82] Our simplifying assumption implies that we disregard certain timing effects. We model the deduction of past R&D expenses at the moment of election to the IP box. This abstracts from positive timing effects of the earlier deduction at higher non-IP box rates, on the one hand (relevant in case of all recapture mechanisms modeled). On the other hand, we also abstract from negative timing effects of a gradual depreciation of chaptalized

account for the fact that accelerated depreciation and super deductions may also need to be recaptured in the patent box: We implement the patent box recapture mechanism on these R&D input-oriented incentives by applying all input-oriented incentives at the lower patent box rate. In the case of machinery and buildings, we assume that depreciations occur only after opting for the patent box. Besides, in all considered countries, the net approach is to be used. Thus, the lower patent box tax rate is decisive to determine the respective depreciation's annual relief.

Table 11: Parameters of Devereux-Griffith methodology

Economic parameters	
True economic depreciation rate (%)	
intangibles	15.35
industrial building	3.10
machinery	17.50
real interest rate (%)	2
inflation rate (%)	0.73
pre-tax rate of return for EATR (%)	20
Composition of investment	
Weighting of financing (%)	
current expenses	90
buildings	3.6
machinery	6.4

Source: Assumptions based on Spengel et al. (2021), Hanappi (2018), Evers et al. (2015).

In line with previous literature, we assume that the company generates sufficient other income to immediately benefit in full from any tax deductions. This is especially important as most R&D tax incentives do not provide a direct cash refund if the taxpayer is tax-exhausted (see Table 9). The assumption of no tax exhaustion is most appropriate in large mature companies that generate income from other investment projects. However, even in a loss scenario, our assumption is not detrimental: In many countries, losses can be offset against future profits using a loss carry-forward. In this case, timing effects only slightly reduce the economic effectiveness of R&D tax, which are negligible in the current low-interest environment. In addition, we provide in the following EATRs with and without R&D incentives, such that one can indirectly deduce the effect of tax exhaustion from these within-country variations in the EATR levels for countries without a R&D benefit refund option. With regard to an R&D tax credit, some countries even allow for an immediate refund, regardless of the tax payment (see Table 9). In this case, losses do not reduce the effect of the tax incentives.

intangibles inside the IP box. Instead, we model an immediate write off in the first period also in case of capitalization of the intangible in the IP box.

In addition to the loss scenario, it also follows from the assumption of full utilization that we do not consider any ceilings (i.e., Spain and US), general limits (Germany) or regressions in the incentive rate (France and Netherlands) for the calculations of the effective tax burdens. Here again we can use our different EATRs (with and without R&D incentive regimes) to compare the lower (full use of R&D incentive) to the upper bound (no use of R&D incentive) EATR value applicable. Moreover, in our model calculations below we assume an incremental investment, and, thus, model incremental schemes and components as well as volume based schemes.

4.4.2. Forward-looking effective tax rates under R&D tax incentives

Table 12 summarizes the main results of our quantitative analysis, which are the EATRs for our sample countries. In our main analysis we assume that the model firm finances the hypothetical investment in a self-developed patent by retained earnings (equity financing). We being our analysis by calculating EATRs in a baseline corporate tax environment without R&D tax incentives. We then gradually add only input-oriented tax incentives, only IP box regimes, and finally both R&D tax incentives.

In a first step, the baseline scenario, we determine the effective average tax burden without considering R&D tax incentives. The first column of Table 12 displays the corresponding EATRs. In this scenario, the corporate income tax rates are the main drivers of the results (see Appendix 14 and Appendix 15 for an overview of the relevant corporate income tax rates and other country parameters). Ireland, with the lowest corporate income tax rate of 12.5%, exhibits the lowest EATR. Germany, France, and Spain, the three countries with corporate income tax rates above 30%, display the highest EATR levels.

To put our results in a wider perspective, we compare our EATRs for a self-developed patent investment to EATR calculations for other investment types studied in the related literature. In comparison to Spengel et al. (2021), who evaluate an investment in a manufacturing firm, we observe on average a one percentage point lower EATR and an up to -2.7 percentage points lower EATR in Ireland and the UK. However, if we compare our results to the effective tax burden of digital investments, we find on average 1.6 percentage points higher EATRs for our patent investment due to less beneficial depreciation allowances on buildings and machinery than hardware and software (Olbert et al., 2019; Spengel et al., 2018).

Table 12: EATR for a self-developed patent considering different R&D tax incentives

Country	Baseline – No incentive	Input incentive	IP box	Input incentive & IP box
Lower inflation / interest scenario – Retained earnings				
Ireland	11.45	-10.35	-5.87	-20.87
United Kingdom	17.45	7.78	9.02	-0.35
Switzerland (Zurich)	19.99	14.06	9.25	8.54
Belgium	22.87	22.47	3.43	3.37
China	22.87	6.89	6.89	6.89
Netherlands	22.95	22.95	6.43	6.43
US (California)	25.67	10.06	25.67	10.06
Germany	28.97	9.45	28.97	9.45
Spain	28.16	-21.76	14.64	-33.42
France	30.08	0.78	10.63	0.11
Average	23.05	6.23	10.91	-0.98

Notes: In our baseline scenario for retained earnings, the lower inflation and interest rate, we use an inflation rate of 0.73% and a real interest rate of 2%.
Source: own calculation and composition

In a second step, we enhance our model by adding input-oriented R&D tax incentives. The second column of Table 12 displays the resulting EATRs. The overall spread of EATRs increases, demonstrating that certain locations become very attractive for investments from a tax perspective if firms use these input-oriented tax incentive regimes. The observed negative EATRs indicate that firms in these countries receive a net subsidy on R&D investments. Furthermore, the ranking of locations according to the EATRs changes dramatically when compared to the baseline scenario. We observe the largest reductions in EATRs in those jurisdictions that offer a very generous tax credit. Countries like Spain and Ireland provide R&D tax credits with abroad tax base and incentive rates higher than the regular corporate income tax rate. Thus, Spain exhibits a very low, even negative EATR of -21.76%, a country that previously displayed one of the highest EATR rates (28.16%).[83] Besides Spain, Ireland is the only other location that exhibits a negative EATR. A similar effect of R&D tax incentives is visible in France, which has, together with the countries mentioned earlier, the most advantageous tax credit in place. However, due to the comparatively high regular tax burden in France, the tax credit does not result in a negative EATR, i.e., a net subsidy of R&D activity.

Belgium, China, and Switzerland, which apply enhanced deductions instead of tax credits, display only a slight reduction in the EATR. In contrast to the tax credit, the benefit of an enhanced deduction is only the multiple of the tax rate. In particular, in Belgium, the enhanced depreciation of machinery has little impact because investments in machinery constitute a

[83] Our result applies to the case of an incremental R&D investment, and holds under the assumption that the firm has enough tax liability such that the tax benefit is not capped. Otherwise, the EATR will be higher.

negligible part of total investment according to our model assumptions, which mirror the typical asset-mix of an R&D intensive company (see above Figure 14). Therefore, we observe the second-highest EATR in Belgium. Only the Netherlands shows a higher EATR equal to the effective tax burden in the baseline scenario. One notable limitation of this analysis is that we cannot model R&D tax incentives that rely on credit against the payroll withholding tax. In our analysis, this restriction comprises the R&D tax incentive of the Netherlands and the wage tax reduction in Belgium. If one was to account for payroll-related tax incentives in the investment decision, the Netherlands and Belgium would become more attractive. A further limitation is that the tax credits modelled here are regularly subject to limitations with regard to the investment volume. Foremost, the German tax credit regime applies only up to a maximum of EUR 2 million in a given financial year and a total maximum of EUR 15 million per project.[84]

In the next step, we evaluate the effect of IP boxes on effective tax rates. Against the background of the Modified Nexus Approach, we assume that the company conducts both the R&D investment and the exploitation of the resulting intangible asset in the same jurisdiction. This assumption assures that all R&D expenditures are eligible for R&D tax incentives. First, only considering the effect of IP boxes, we see a reduction of effective average tax rates in all countries that offer an IP box regime. Ireland shows the lowest EATR and is the only country that exhibits a negative EATR with a rate of -10.35% (i.e., an investment subsidy). This relatively strong reduction results from the fact that Ireland has no recapture mechanism in its IP box: Ireland allows for a deduction of expenses related to IP box income at the higher regular corporate income tax rate, while profits are taxed at the preferential IP box rate (see above Table 10). Especially the comparison to Evers et al. (2015), reflecting the situation pre-Modified Nexus Approach, shows significant increases in the effective tax burden due to the applicable net income approach and mandatory recapture mechanisms. While Belgium, Spain, and France offered implicit tax-subsidies for patent investments in 2014, the tax burden increased nowadays to up to 14.6 percent in Spain. Further, when comparing the effects of the IP box regimes overall to the effects of the input-oriented incentives, the extremes to the lower end of EATRs are less pronounced. In all other countries with an IP box regime, the EATR lies just below the IP box income tax rate. For instance, in Belgium, the EATR is reduced to 3.43% due to a low IP box rate of only 4.44%. In Spain, we observe the highest EATR for a country with

[84] Therefore, our baseline scenario as well as the R&D tax incentive scenario represent both extremes: If a firms is above the overall threshold of eligible R&D investment, the corporate tax burden on an additional R&D investment is given by the baseline scenario. Whereas, if a firm does not run into the overall limitation of the financial tax benefits, the second column determines the tax burden on this investment.

an IP box regime, with an EATR of 14.46%. Nevertheless, this is a reduction of almost 10 percentage-points compared to an average EATR in the baseline scenario of 23.05%.

As the final step, we consider input- and output-oriented R&D tax incentives simultaneously in the tax assessment and compare this with the situation without or the partial application of R&D tax incentives. In this combined scenario, Spain has the lowest EATR. Table 12 shows that the attractiveness of the input-oriented incentives drives this effect. The second-lowest effective tax burden, with -20.87%, is visible for Ireland. The effect stems from the combination of the very generous R&D tax credit and the missing recapture rule in the IP box regime. In general, we observe that the combination of both tax incentives further reduces effective tax burdens on R&D investments. We make similar observations for the United Kingdom and France, although, in the latter, the overall percentage point change is lower than in the United Kingdom.

To check for the sensitivity of our results to the underlying assumptions, we provide some additional analysis in Appendix 17. If we consider a scenario of a fully debt-financed investment, the results do not change substantially. Also, a comparison with a high inflation/interest rate scenario does not change the conclusions drawn from our principal analysis; however, the overall level of the EATRs is lower, because higher interest rates increase the timing benefits of depreciations and other deductions.

Appendix 16 shows that France, Spain and Switzerland have comparatively strong deviations from our assumed composition of R&D expenditures (i.e., 90% current, 10% capital). When we account for these country-specific compositions in our EATR calculations, we observe minor reductions in the effective tax burden for Spain and Switzerland due to a higher ratio of current R&D expenses being immediately deductible from the tax base (Appendix 18). While, we observe the opposite for France, given the higher investment in capital assets, especially machinery. Despite slightly higher deviations from our results in France, the sensitivity analysis in Appendix 18 shows that our results are robust to country-specific asset compositions.

We can summarize that the studied high FDI countries continue to rely heavily on R&D input-oriented incentives and IP boxes, i.e., output-oriented incentives. Further, we find that R&D tax incentive regimes have pronounced effects on the tax attractiveness of the location for R&D investment decisions. Our model shows a substantial impact on EATRs as a measure of location attractiveness, of on average 24 percentage points if both instruments are combined. Considering only the partial introduction or usage of either IP boxes or input-oriented R&D tax incentives, we observe an average reduction of 14.5 percentage points for IP boxes and up to 18.7 percentage points in the case of input-oriented R&D tax incentives. The total range of

EATR reductions relative to the baseline scenario lies between 62 percentage points in Spain and 11 percentage points in Switzerland. Spain's example as a high-tax country with very favourable R&D tax incentives demonstrates that countries can use R&D tax incentives to generate considerable differentiation between the taxation of different corporate activities. There we are able to show how tax credits and patent boxes can work together to generate extreme EATR reductions. Instead, in other countries the relative benefit of input-oriented benefit regimes, depending on the tax rate (e.g. Switzerland), declines in the presence of IP boxes.

4.5. Discussion of findings based on the related literature

In this chapter, we discuss our findings in light of the empirical literature with regard to the studied R&D tax incentives' effects on a) increasing R&D activity, b) profit shifting, and c) location choice.

4.5.1. Effectiveness of R&D tax incentives in increasing investment

Due to their long existence, there is a large body of research on the effectiveness of input-oriented R&D tax incentives. According to the majority of studies, input-oriented R&D tax incentives are effective in increasing R&D expenditures (Appelt et al., 2016; Becker, 2015; B. H. Hall & Van Reenen, 2000). Overall, empirical findings suggest that the price elasticity is around unity or higher depending on the country evaluated. Recent empirical evidence for the countries we consider largely confirms these results (Mulkay & Mairesse, 2013; Rao, 2016).

The empirical literature finds that firm size matters for how much firms can benefit from input-oriented R&D tax incentives. For the UK, based on evaluating changing SME thresholds and changing incentive rates, Guceri and Liu (2019) as well as (Dechezleprêtre et al., 2020) find that younger firms show a higher responsiveness to input-oriented R&D tax incentives. Furthermore, Guceri and Liu (2019) provide evidence that artificial relabelling does not drive the observed increase in R&D activity. Equally, in the Netherlands, Lokshin and Mohnen (2012) find a higher responsiveness of young SMEs to the Dutch input-oriented R&D tax incentives regime. Contrary to these findings, Acheson and Malone (2020), studying the effect of the introduction of a refund possibility in the Irish R&D tax incentives regime, conclude that, in the Irish case, the increase in R&D is mostly attributable to large companies, although the policy targets small, tax-exhausted firms. In Spain, the empirical evidence on who benefits from the generous input-oriented R&D tax incentives is mixed. Corchuelo and Martínez-Ros (2010) find that large firms drive the effect, whereas Labeaga et al. (2014) show higher responsiveness of SMEs. Furthermore, Labeaga et al. (2020) show that the persistent use of R&D tax credits is particularly effective for the achievement of product innovations by SMEs. However, the authors also indicate that only a minority of firms participate on a regular basis in the Spanish tax incentive scheme.

Furthermore, the literature highlights that the effectiveness of input-oriented R&D tax incentives depends on a variety of factors, such as on the particular tax instrument in place. For example, in Belgium, Dumont (2019) finds a strong positive effect on research activities from the partial withholding tax exemption on R&D employees (not modelled here). In contrast, Dumont (2015, 2019) finds no effect of the Belgium tax credit on research activities modelled in this paper. The finding that R&D tax credits have little effect, contradicts studies that find R&D credits in other countries to be very effective in increasing R&D activity. However, the null finding may be due to the comparably small tax base and low incentive rate in Belgium (see Table 9, see also the small effect on the EATR observed in Table 12).

China is a country that is particularly interesting to study as, in contrast to classical industrial countries in Europe and the US, it still exhibits strong investment growth. Jia and Ma (2017) and Chen et al. (2018) find that in China firms react strongly to input-oriented tax incentives for R&D investment. For example, a 10% reduction in R&D user costs leads to an increase in R&D spending of 3.97% (Jia & Ma, 2017). However, Chen et al. (2018) caution that the evidence suggests that the observed reaction to R&D investment incentives may be largely due to relabelling. Despite indication for relabelling, the authors show that tax incentives have a positive impact on firm productivity.

Evidence on whether tax incentives stimulate additional firms to conduct R&D is limited (i.e., evidence on extensive margin responses), as most studies focus on the evaluation of the intensive margin. An exception is Bozio et al. (2014)s’ finding that in France input-oriented R&D tax incentives let to an increase in the number of R&D performing firms. However, the responsiveness to the incentive is much smaller for newly R&D performing firms than for already R&D performing firms. Overall, R&D input-incentives seem to increase R&D activity, although relabelling may be an issue in particular in emerging economies.

We next turn to evidence on the effectiveness of output-oriented R&D tax incentives in increasing R&D activity. A number of researchers have studied the evidence on patent activity as well as R&D activity in response to the introduction of an IP box. In general, there is limited evidence on the encouraging effect of IP boxes on innovation activity within the IP box country. Gaessler et al. (2019) evaluate 13 IP box regimes in an analysis of all registered patent ownership information changes of patents granted or validated in Germany between 1981 and

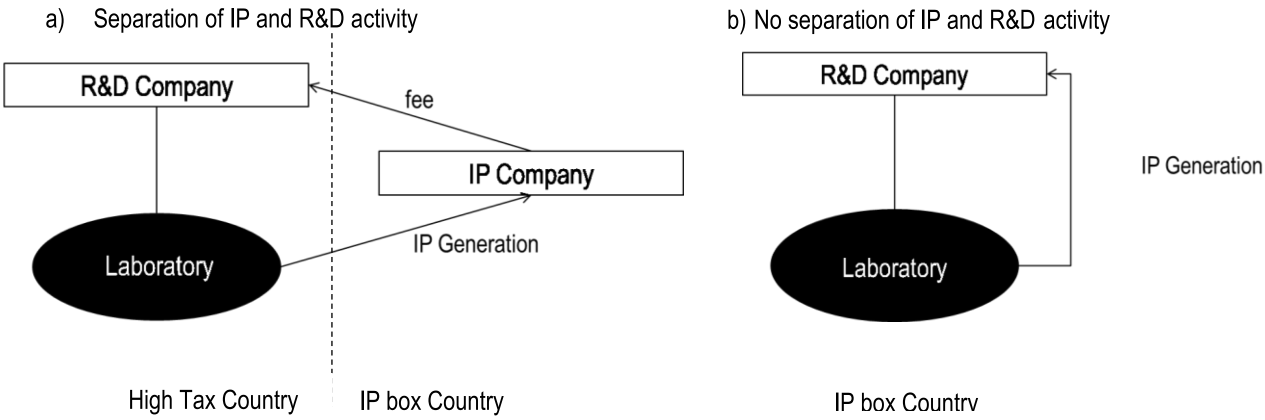
2014. They do neither find an effect on patented inventions nor R&D investment. This is in line with the result of Alstadsæter et al. (2018) who do not find a significant increase in local innovation activities for the pharmaceutical, car and the information communication technology-industry after the introduction of IP boxes. This null finding can be explained by the timing of the IP box benefit. In contrast to input-oriented incentives, IP boxes, which apply to the outputs of R&D activity, cannot overcome liquidity constraints in the research phase that often constitute the central obstacle to innovation.

In addition to the lack of evidence of an increase in R&D activity, we view another feature of IP boxes as highly critical; the de facto selectivity of industry-specific accessibility of IP box regimes. Not all outputs of R&D activity benefit from IP box regimes, which are with few exceptions limited to profits from patents and related rights, i.e., royalty income on qualifying assets. Yet, patents and related royalty payments play a central role in only a small number of industries. 99.5% of all patents are granted to firms in the chemical, electrical, engineering, information and communications technologies and pharmaceutical industries (Alstadsæter et al., 2015; Spengel, 2016). Based on the organizational structure of firms in, e.g., the pharmaceutical industries one can assume that a substantial portion, if not all profits of firms in these industries will be able to benefit from IP box regimes, in principle, while, e.g., the service sector cannot profit from IP box regimes (if embedded royalties are excluded from the scope of the IP box). This implies that IP boxes de facto generate substantial competitive distortions between industries, caused by the selectivity of the granted benefits which may go so far as to violate EU state aid law Spengel (2016).

4.5.2. Profit-shifting effects of R&D tax incentives

Although the literature finds largely no effect of IP boxes on local R&D activity, it is well established that corporate income taxes are a significant determinant of patent location choices (Bösenberg & Egger, 2017; Griffith et al., 2014). High corporate income taxes deter firms from locating patents in these countries (Ernst & Spengel, 2011; Karkinsky & Riedel, 2012). Simultaneously, the literature shows that IP boxes attract patents and that the related income inflows increase with the generosity of the IP box (Alstadsæter et al., 2018; Ciaramella, 2017). In line with these findings, Koethenbuerger et al. (2019) show that the introduction of IP boxes does not only lead to an inflow of eligible income as it further prevents the outflow of IP income. Chen et al. (2019) show that in countries with the most generous IP boxes, a one percent decrease in the statutory tax rate is associated with approximately 14.83% less IP-income shifting out of the country.

Figure 15: R&D investment via R&D Company & IP Company



Source: own illustration and calculation

Figure 15a) depicts schematically how the mobile nature of IP assets facilitates profit-shifting: A multinational with R&D activity in a high tax country (the R&D Company) sets up a subsidiary (the IP Company) in an IP box country, which holds and exploits the IP asset. Such a set up allows the separation of the place of development and exploitation. The multinational can benefit from the preferential IP box tax rate on patent income while deducting R&D expenses at a high corporate tax rate. Furthermore, the firm can benefit from the high tax country's infrastructure, regulatory environment, and skilled personnel. To book the profits from R&D activity in the IP box, the IP Company must bear the full risk of the development and financing of the IP asset, which can be ensured by contractual relations. In such a scenario, the IP Company pays a small fee to the R&D Company for carrying out research. This fee is based on the costs incurred, increased by an arm's length mark-up. Royalties are directly due to the IP Company (Evers, 2015). The patent can be located from the beginning of the IP generation phase in the IP box country or transferred to the IP box country.

The Modified Nexus Approach's introduction intended to prevent such purely tax-driven patent location and ownership transfers since it requires the claiming entity to carry out (a substantial part of) the related R&D activity itself. If firms want to benefit from the IP box regime under the Modified Nexus Approach, the development (R&D Company) and exploitation (IP Company) has to be located in the same legal entity, as depicted in Figure 15 b).

Nevertheless, the Modified Nexus Approach's introduction did not solve all problems associated with IP profit shifting by IP boxes. It leaves open the back door of shifting profits to permanent establishments instead of a separate legal entity (Fabris, 2019). Furthermore, Koethenbuerger et al. (2019) demonstrate that firms combine the use of IP boxes with out-ward profit shifting activities of regularly-taxed income. They observe that firms that use IP boxes also increase income shifting via interest payments on internal debt. If interest payments are deductible at the standard tax rate, outside the IP box, while profits are taxable at the lower IP box rate; this may even result in an effective tax burden below zero in the IP box location.

4.5.3. Location choice effects of R&D tax incentives and tax competition

The empirical literature suggests that IP boxes may play a central role in firm location choices. First, IP boxes could be a tool to reduce the transfer of patents and related R&D to low-tax countries, especially if IP boxes require a kind of nexus such as in the form of further development conditions under the Modified Nexus Approach (Alstadsæter et al., 2018; Bradley et al., 2015; Gaessler et al., 2019). Second, Schwab and Todtenhaupt (2019) point out that the introduction of nexus requirements prevents cross-border spill over effects within multinationals and could lead to distortions of international location choices. As companies are now constrained in their options to shift patents to low-tax countries, they could instead decide to move the underlying real activity. The authors point out that this is of higher risk for low-tech manufacturing companies as these businesses require fewer specific investments in human and fixed capital and, therefore, have lower relocation costs.

Also, input-oriented R&D tax incentives can affect location choices. Wilson (2009) finds for the US evidence that firms reacted to input-oriented R&D tax incentives by relocating R&D activities within the US instead of increasing R&D activity overall. Therefore, if more and more countries rely on R&D tax incentives, countries not following this trend could be disadvantaged in the global competition for R&D investments.

4.6. Conclusion

In recent years, the development of R&D tax incentives, input-oriented incentives, and IP boxes has been highly dynamic. Due to international scrutiny on preferential tax regimes, countries rely increasingly on these tools to attract foreign R&D activities and income and stimulate domestic innovation activity. Besides the general innovation environment, infrastructure, and human resources a country offers, company taxation has a large influence on the location attractiveness of R&D activity. We show by means of a neo-classical investment model that the tax attractiveness of the studied locations increases substantially as soon as one accounts for R&D tax incentives. We find that the EATR on R&D investments is reduced by 24 percentage points on average in our sample of important FDI countries relative to the base scenario without incentives. In some countries, EATRs on R&D investments are even negative, which shows that governments are effectively subsidizing investments into R&D.

Although we find that both output- and input-oriented R&D tax incentives induce reductions in EATRs and therefore increase countries' tax attractiveness, we point out that there are important differences between the effects of the two, not only with regard to the effectivity in incentivizing real R&D. The literature almost unanimously shows that if sufficiently large, input-oriented incentives do spur R&D investment. However, increases in R&D investments may be due to the relocation of R&D activities and not an overall increase in R&D activity.

Therefore, with a view to competitive effects, we caution that if more and more countries rely on R&D tax incentives, this could disadvantage countries not following this trend. In contrast to input-oriented tax incentives, the empirical literature finds for IP boxes, as output-oriented tax incentives, that these are often ineffective in increasing R&D investment. Furthermore, IP boxes have induced profit shifting, which may still be the case in certain circumstances after the Modified Nexus Approach. Additionally, the Modified Nexus Approach's introduction may incentivize firms to relocate real activity instead of profits to low-tax countries, distorting optimal capital allocation. At the same time, evidence suggests that IP boxes based on the Modified Nexus Approach may effectively prevent the outflow of R&D assets and outputs to low-tax countries. Another criticism against IP boxes is their de facto selectivity, which can imply substantial competitive distortions.

Our study demonstrates that R&D tax incentive regimes strongly affect the tax attractiveness of countries for R&D investments. Especially in the age of digitalization, it does not suffice to consider statutory tax rates to evaluate the tax attractiveness of a country. The appropriate measures are instead EATRs that account for R&D tax incentives, such as the once developing this paper. In a technology-based economy, the taxation of R&D investments will be of increasing relevance, and, therefore, R&D tax incentives will play an even more critical role in international tax competition.

In light of the debate on a post-Covid EU recovery plan, we reiterate that the current R&D incentives in place in some countries constitute strong instruments to attract investments. In the broad field of potential tax alleviations, R&D tax incentives have a particular important role in overcoming crises; in contrast to a general reduction of the corporate income tax, R&D tax incentives have the advantage of setting a targeted incentive for the attraction of innovative investments. With currently tight government budgets, this more efficient tax alleviation for businesses should be preferred. However, based on previous empirical findings, likely only input-oriented incentives can effectively enhance R&D activity, with tax credits constituting particularly strong incentive mechanisms. The strong tax competitive situation, we observe in some countries in our analysis, i.e., the divergence in EATRS, once we account for R&D tax incentives, also highlights that those countries, which do not rely as heavily on tax R&D regimes, need to invest in their R&D attractiveness. A common European approach to R&D tax incentives could evade dangers of intra-European tax competition for R&D activity that may distort optimal capital location. We hope that this paper can be a first guide in taking a direction in the use and choice of R&D tax incentive instruments.

5. Does Nexus Pay Off? Implications of the Modified Nexus Approach on Effective Tax Burdens and Tax Planning Strategies of Multinational Enterprises[85]

5.1. Introduction

Innovations are a key driver of countries' economic growth and social welfare (Hasan & Tucci, 2010). During the last decade research and development (R&D) activities for innovative intellectual property (IP) became increasingly important for companies as well as for the overall economy (Karkinsky & Riedel, 2012). The crisis highlighted the value of innovations, as the speed of development for new vaccine patents as well as for new technologies intensely increased (Wagner et al., 2021). Thus, IP as one major fruit of innovation, impacts most industries and generates vast amounts of corporate income especially of multinational enterprises (MNEs) relying on a cross-country knowledge network (Berry, 2014; Singh, 2008).

As IP is characteristically tremendously agile, in that the relevant R&D activities can be carried out and markets can be served with goods and services without requiring a significant physical presence on site, it can be relocated within the MNEs in a time- and cost-efficient manner (Baumann et al., 2020; Markusen, 1995). Thus, companies are flexible in choosing their geographic location (Akcigit & Stantcheva, 2020; Huang et al., 2020), whereas, governments are willing to attract corporate taxpayers to increase fiscal income by providing targeted tax incentives (Cabral et al., 2021).[86] In 2021, 13 EU member states and the UK offer a preferential tax treatment of income accruing from certain intangibles. Besides an increasing adoption within the EU, we observe a growing number of IP boxes in non-EU-countries (e.g., Canada, Israel, Serbia, Switzerland, and Turkey). The significantly lower effective tax rate for specific types of IP-related income compared to the general corporate income tax rate in the respective countries constitutes the main characteristic.

However, one drawback of the high flexibility of MNEs is the increase in base erosion and profit shifting (BEPS) opportunities. The OECD established the Modified Nexus Approach (henceforth: "the nexus") which was established in 2016 and set certain boundaries to the overall generosity of IP boxes by linking the grant of incentives to a certain degree of local

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[86] For the decision about the location of patents under tax considerations, see Karkinsky and Riedel (2012).

substantial activities (OECD, 2015b). As minimum standard the nexus requires theoretically rather homogenous IP box characteristics (e.g., qualifying assets, treatment of expenses) compared to the previously heterogeneous regimes in terms of scope and overall generosity across countries.

In this paper, we evaluate qualitatively if the nexus and its national implementation is effective in aligning IP box regimes with the objective of fostering domestic R&D activities, on one side, and in restricting harmful tax competition, on the other. Moreover, the qualitative analysis will be transferred into quantitative values, namely effective tax measures by behalf of the Devereux-Griffith methodology. In this analysis, we examine the tax treatment of domestically operating business models in the legal form of a corporation under the regular tax system and compare the absolute and relative advantageousness in the pre- and post-nexus era of IP box regimes in Europe for a fictitious R&D project. Thus, our paper contributes to the existing research on IP boxes by providing a qualitative and quantitative overview of the changes in European IP box characteristics pre and post the nexus enactment.[87]

Our main results show, that the nexus effectively prevents negative effective tax burdens, i.e. an implicit subsidy, which indicates that aggressive tax planning concerns are reduced. However, by incorporating input-oriented R&D tax subsidies along with IP box regimes into the analysis, we reveal that the nexus is likely to accelerate a race to the bottom by creating incentives to extend the benefits of internationally recognized input-oriented tax incentives as we could observe highly negative EATRs. Even though the nexus increases the harmonization of certain IP box characteristics, there is still a high leeway in designing possible simultaneously applicable R&D incentives or general notional interest deductions.

This article is organized as follows: In Chapter 5.2, we highlight changes in the tax planning on behalf of IP since the implementation of the nexus. Chapter 5.3 introduces the nexus and provides a qualitative overview of existing IP boxes as R&D tax incentives in Europe. Afterwards, in Chapter 5.4 we give a brief overview of the methodology and describe the model implementation of the nexus of IP box regimes. We then present our main results and discuss them in Chapter 5.5. Based on our effective tax rate indicators, we evaluate the impact of the IP box regimes and, in particular, consider the impact of the nexus based on different scenarios. Moreover, debt-financing and different nexus quotients are implemented in our sensitivity

[87] For a detailed overview on the heterogeneous design of IP boxes in the pre-nexus period, see Evers (2015).

analysis. In addition, we examine the effect of possible combination of out- and input-oriented R&D tax incentives. Chapter 5.6 concludes.

5.2. Evolution of IP tax planning during the last decade

In a globalized world, multinationals face severe pressure of competition but also heterogeneous tax environments across the states. This heterogeneity allows them to exploit international differences in tax rates and tax bases, aiming to reduce the group's overall tax burden given a certain level of profitability (Endres & Spengel, 2015).[88] In this context, IP is an especially well-suited instrument to establish tax-efficient structures due to its missing clear geographical connection as well as a missing arm's length price for transfer pricing. It is well known that MNEs exploit these features primarily to maximize their tax benefits by disentangling the location of IP ownership from the location of the underlying R&D activity in the pre-nexus era at comparatively low (non-tax) cost (Böhm et al., 2015; Griffith et al., 2014). To do so, they transfer the IP to a permanent establishment or subsidiary located in a low-tax country without simultaneously relocating the R&D activity (Alstadsæter et al., 2018; Baumann et al., 2020; Böhm et al., 2015; S. Chen et al., 2019; Ernst & Spengel, 2011; Eynatten, 2008; Griffith et al., 2014; Koethenbuerger et al., 2019). This allows them to maintain their R&D activities in a high-tax country with a good innovation infrastructure or generous input-oriented R&D tax incentives, ensuring that the (additional) deduction of R&D expenses reduces the domestic tax liability in the development phase. A subsequent minimization of an MNE's global tax burden is ensured by tax benefits associated with the relocation to a low-tax country in the exploitation phase. The bundling of IP assets is often achieved by establishing an IP holding company that grants licenses to affiliated intra-group companies (Maine & Nguyen, 2017). In this way, royalties reduce the tax bases of the licensees located in countries with higher corporate tax rates, while the licensor faces low tax rates on its royalty income.

Moreover, as innovation classifies as one key driver of economic growth and firm value, many states provide a diverse selection of beneficial tax rules for IP. MNEs could exploit these existing input-oriented (e.g., R&D tax credits, enhanced deductions) or output-oriented R&D tax incentives (e.g., IP boxes)[89] in the majority of OECD countries. Thus, the empirical evidence for higher R&D activities being associated with more tax planning is not surprising (Gao et al., 2016). The increasing introduction of preferential tax rates (i.e., IP boxes) raised

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[88] Other studies find evidence that tax rate differential between subsidiaries impacts the locations of R&D activities, e.g., Bloom and Van Reenen (2002) and Hines (1994).

[89] Some authors refer to the synonym income-based, see Lester & Warda (2018).

public attention as a tool for international tax planning merely used by MNEs during the last decade (Heckemeyer & Overesch, 2017). These lower tax rates on IP income enable high-tax countries to compete with classical tax havens, which intensified the international tax competition on IP asset locations and the risk of domestic tax base erosion. The initial idea behind IP box regimes is twofold: to prevent domestic IP assets from being transferred abroad, and to attract innovative companies to increase national R&D activities that positively impact a country's overall economy (Böhm et al., 2015; Klemm, 2010).

Various studies show that a reduction in the corporate tax rate can, in principle, lead to an increase in patent registrations. However, this effect occurs mainly in countries with already implemented R&D tax incentives and thus, created sensitivity among stakeholders (Dischinger & Riedel, 2011). Recent empirical work confirms that the initial design and scope of IP boxes and their accompanying tax cut mainly increased the number of cross-border transfers of high-value patents to countries introducing preferential tax rates on IP income, rather than stimulating additional domestic R&D activity (Alstadsæter et al., 2018; Ciaramella, 2017; Schwab & Todtenhaupt, 2019).[90] The use of other profit-shifting channels by MNEs to shift regularly taxed income out of an IP box country further indicates that the patent location is driven mainly by taxes (Ismer & Piotrowski, 2015; Koethenbuerger et al., 2019).

To avoid the emerging tension between harmful IP-based tax planning, i.e., profit-shifting, and the accepted increase of primary R&D activities by supportive instruments, the OECD developed within Action 5 of the BEPS project the modified nexus-approach (OECD, 2015b; Pinkernell, 2014). Put simply; the nexus aims to address mismatches between the locations where profits are booked and where profits are generated. It restricts the scope of application to trade intangibles, i.e., patents and functionally equivalent IP assets,[91] and approximates economic substance, i.e., R&D activity, by R&D expenditure (Traversa & Flamini, 2018; with further evidence Schwarz Martínez, 2017). Therefore, a taxpayer benefits from IP only to the extent that the taxpayer incurred qualifying R&D expenditure that gave rise to the IP income (OECD, 2015b). R&D expenditure act as a proxy for substantial activities because IP regimes

[90] Bornemann et al. (2018) show that the Belgium IP box does not significantly increase patenting activity (applications). Alstadsæter et al. (2018) do not find an indication of inducing innovative local activities. However, Schwab and Todtenhaupt (2019) highlight that those strategies can also lead to positive spillover effects.

[91] The functional equivalency is proven by legal protection and, if relevant, by a patent-like approval and registration process. Exclusive rights for using IP, legal remedies against infringement, trade secret law, and contractual and criminal protections against the use or unauthorized disclosure of information linked to the IP belong to legal protection, see OECD (2015b). For a detailed explanation of the personal and factual scope of application and further evidence, see Schwarz Martínez (2017).

are typically designed to encourage R&D activities and foster growth and employment. In line with this argumentation, the restriction to trade intangibles ensures that only IP assets that result in positive (R&D) spill overs benefit from the preferential tax rate.

The introduction of the nexus represents one of the most significant turning points in IP tax planning, as it subjects global IP holding practices to closer scrutiny. The more rigorous substance requirement excludes various types of IP assets (e.g., purely acquired patents without any further development) from the scope of qualifying income of IP boxes. Additionally, it limits intangible asset mobility as the cross-border separation of R&D activity and IP location reduces or even prohibits IP box tax benefits.[92] Therefore, taxpayers who wish to benefit from IP regimes should incur actual expenditure on such activities in the respective location.

However, the nexus ensures that MNEs engage in domestic R&D activities and reinforces the importance of input-oriented R&D tax incentives for qualifying R&D expenditures. As a result, international IP tax planning changes significantly, given that separating R&D activities from IP exploitation no longer necessarily leads to the most tax-efficient outcome, at least in the European Union. Instead, MNEs favour the centralization of R&D activities and IP, especially within a legal system that offers both generous out- and input-oriented R&D tax incentives. This development also increases the risk of relocating real research activities, especially for new R&D investment location decisions. The exit taxation regarding the offshore shifting of activities or companies can be an essential obstacle in reducing the corporate tax burden for existing structures. Contrary to the buying or licensing approach, when bundling R&D activity and IP in one country is not possible, cost-sharing agreements offer a more tax-efficient design choice in the nexus era.[93]

In summary, in the post-nexus era, the national legislators must provide a set of tax incentives that reduce the group's overall tax liability to increase the attractiveness of their locations in tax competition. However, as the nexus requires MNEs to relocate tax bases and underlying R&D activity to achieve the IP box incentive, a distortion of international location choices is possible (Schwab & Todtenhaupt, 2019). Thus, this group-wide tax planning in favour of the states that provide the whole bundle of tax incentives will not reduce the intensity of international tax competition. Therefore, in the following, we examine the quantitative impact of post-nexus tax incentives on this race to the bottom in the tax burden in the context of location attractiveness.

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[92] Schwab and Todtenhaupt (2019) found empirical evidence that a cross-border effect for nexus IP boxes is on average close to zero and significant negative for low-tech manufacturing firms.

[93] For a detailed explanation and discussion of this approach, see Heyvaert (2018) and Graetz and Doud (2012).

5.3. Qualitative overview on the status quo of existing European IP box characteristics

In our analysis, we cover the most important features determining the generosity of all existing IP box regimes within the European Union as of 2021. Further, we include the IP boxes introduced in Switzerland[94] and the UK. All of these national IP box regimes have to be in line with the nexus, which is mandatory as of 30 June 2016. Further, the grandfathering rules for IP assets brought into IP box regimes which existed before the nexus introduction ended in 2021. Still, we observe heterogeneous definitions of certain design characteristics, which could influence the tax planning incentives.

The most salient feature of IP box regimes is their preferential tax rate on IP income. As of 2021, the effective IP box rates range from 1.75% in Malta to 12.975% in Italy. This results in a substantial percentage point (pp) decrease in the statutory tax rate applicable to IP income (e.g., of up to 33.25 pp in MT). The covered IP box regimes apply different **relief techniques** to achieve lower effective tax burdens (see Table 13). In most countries, we observe a partial exemption of the qualifying IP income, i.e., a reduction of the tax base by either a full (pro-rata) exemption of qualifying income or a lump-sum deduction of business expenses (Graetz & Doud, 2012). Therefore, adjustments to the IP box tax rate occur not only when the share of tax-exempt income changes but also when the corporate tax rate changes. Whereas in the earlier periods, in most countries the share of exempt or deducted income constituted up to 80% (Evers, 2015), nowadays half of the countries only exempt up to 50% of the qualifying IP income. Still, the majority of countries reduce their IP box tax rate in comparison to 2014, which is mostly driven by a decrease in the regular corporate income tax rate. Malta and the Netherlands are the only countries in our sample in which MNEs face a higher effective tax rate on IP income in 2021 compared to 2014. Besides the Netherlands, the regimes in France, Lithuania and Poland explicitly stipulate a preferential tax rate for IP income.

In addition to the amount of the partial exemption or the level of the preferential tax rate, it is decisive how tax surcharges and local taxes are dealt with. The treatment of these surcharges varies substantially from a full exemption (i.e., of the business and innovation tax in HU)[95], a partial consideration (i.e., at the cantonal level in CH)[96] to a full consideration (i.e., ES[97], FR, IT, LU, PT).

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[94] We restrict our analysis to the IP box of the canton Zurich.

[95] For more information, see Deloitte (2021b).

[96] For more information, see Uebelhart and Bellwald (2019), Zürcher Steuerbuch (Merkblatt Patentbox, 2020).

[97] The local business tax in Spain represents a special case as it is a non-income tax on business capital. Due to its nature as a business tax on capital the tax base is not dependent on the profit situation of an MNE. Following

Within Europe, only Hungary and Slovakia apply a general limitation of the IP box benefit. Whereas Hungary restricts the amount of the deduction to 50% of the taxpayer's pre-tax profit, Slovakia limits the tax benefit to periods in which depreciation write offs from capitalized costs on patents are reported as tax-deductible expenses.[98]

In addition to the preferential tax rate, the generosity of the existing IP box regimes is also determined by the specific design of the tax base, which is strongly affected by nexus. The most relevant feature is the nexus ratio, which comprises first, the scope of qualifying IP, second, the type of eligible income and third, the treatment of current and historical expenses. These features altogether determine the overall generosity of existing IP box regimes.

As mentioned previously, the nexus requires a certain degree of the taxpayer's substantial activity in the IP box jurisdiction. This is to ensure that the purpose of the IP box to encourage additional (domestic) R&D activities is achieved by limiting the application of the beneficial tax treatment to taxpayers participating in R&D activities. Therefore, the nexus applies a preferential IP box tax rate to certain IP-related income ($I_{overall}$) in proportion to the nexus ratio, i.e., the share of own, qualifying R&D expenditures ($E_{qualified}$) to overall R&D expenditures ($E_{overall}$). The share of income which may receive the IP box treatment is calculated by the following formula:

$$I_{qualified} = \frac{\min\,(1.3 \times E_{qualified}, E_{overall})}{E_{overall}} \times I_{overall} \qquad (10)$$

The characteristics of the various parameters are sovereignly determined by the national jurisdiction within the limitations set by the OECD (2015b). In general, expenditures are regarded as qualified if they are directly linked to the IP asset and only incurred for actual R&D purposes by the qualified taxpayer. Building costs and other non-separable capital costs lack in the establishment of a direct relationship between a particular IP asset and those expenditures. Moreover, a 30% up-lift in expenditures is permitted and is also implemented by all countries considered to increase the amount of qualifying expenditures up to overall expenditures. This up-lift intends to address the unreasonable discrimination of taxpayers who predominantly generate non-qualifying expenditure, i.e., outsource R&D activities, but who are still responsible for a large part of the value creation (including costs and innovation risk).

existing literature, we do not consider it in the evaluation of the IP box regime. For more details on the Spanish local business tax, see Spengel et al. (2021), B-27.

[98] HU: IBFD (2021, sec. 1.4.6); SK: Council of the European Union (2018b).

Overall expenditures include expenditures that would have been qualified if they had been incurred directly by the taxpayer itself. Thus, non-qualifying expenditures are not included, even if they were undertaken by the taxpayer. In addition, acquisition costs and expenses for contract research carried out by related parties are also considered as overall expenses (OECD, 2015b).

The parameter overall income depends on the national legal definition of income, including the mandatory application of transfer pricing rules. Regarding the scope of **qualifying IP** assets, all observed IP box regimes follow the OECD guidelines and restrict the eligibility to trade intangibles, which should provide higher positive spill over effects due to real R&D activity (Arginelli, 2015). In addition to patents, all IP box regimes, except Switzerland and the UK, include software protected by copyright. However, in both countries, it is possible to include patents that relate to computer-implemented inventions (so called "software patents").[99] These software patents cover computer-technical controls, but also software-based systems such as robotics, artificial intelligence, cryptography and cyber-physical systems. Moreover, some IP box regimes apply to a wider scope of IP assets which could include utility models, designs and models, plant breeders’ rights, orphan drug designation as well as secret formulas and processes (for an overview of the qualifying IP assets, see Table 14). Besides self-created eligible IP assets the observed regimes still comprise acquired IP assets given further development.

Qualified types of income, i.e., income that is subject to the preferential treatment of the IP box, are income from the transfer of use of licenses (royalties), income from the sale of the qualified IP, as well as from the internal exploitation or use of qualified IP. The consideration of the latter category shall prevent an unequal treatment of companies that internally use qualified IP. Thereby, it must be distinct, if the income is generated by sales revenues from products or services that contain qualified assets (i.e., embedded income) or if the income results from fictitious licensing.[100] Fictitious licenses refer to income that is linked to the use of qualified IP for the operation of the company’s own business process (e.g., production of finished products, execution of services) and would have to be paid if the qualified IP is owned by a third party (Evers, 2015; Schwarz Martínez, 2017). The majority of countries makes use of the broad range of qualifying types of income, which is suitable to achieve a tax incentive that is not sector- or industry-specific and thus avoids distortions of competition (Spengel,

[99] For more details for CH, see Balmer Etienne and IPrimer (2021), and for the UK, see HM Revenue & Customs (2021a).

[100] The implementation of embedded income requires an additional method to distinguish income related and unrelated to IP, e.g., BEPS conform transfer pricing principles (OECD, 2015b).

2016). Still, France, Lithuania, Portugal and Spain exclude IP income from the internal exploitation or use. Therefore, in this subset of countries, the IP box creates a significant distortion of competition among industries that rely heavily on the internal use rather than generating profits through a licensing model (Spengel, 2016). With regard to capital gains we observe various treatments, ranging from full exemption in Cyprus and Hungary to no inclusion of capital gains in Ireland. In Belgium and Italy taxpayers need to fulfil a reinvestment condition to benefit from the preferential treatment. Italian beneficiaries have to reinvest at least 90% of the proceeds, within the following two tax years, in R&D activities of other qualifying IPs (Gallo, 2018). In Belgium the reinvestment period of five years is slightly more generous, however capital gains only qualify if the underlying IP is a fixed asset and is held for more than 24 months (Komlosi, 2017).

For determining the tax base of IP box regimes, the **treatment of current expenses** (i.e., depreciation allowances incurred on the use of capitalized IP, administrative expenses, improvement expenses, and financing expenses) related to qualifying income differed substantially in the past.[101] IP boxes either allowed the deduction of current expenses against regular taxed income (gross approach) or restricted it to preferentially taxed income (net approach). The tax deductibility of current expenses shields income from taxation, i.e., a tax shield whose value is determined by the applicable tax rate. A deduction of current expenses from the profit subject to regular taxation leads to an asymmetrical treatment and thereby enables tax arbitrage[102]. To ensure that the tax benefit is proportionate to the expenses and income incurred, the nexus, therefore, prescribes the net approach. Further, companies have to allocate income and respective expenses on each qualified IP asset separately.[103] In line with this requirement, all IP boxes considered apply the net approach for calculating the IP box base.

Closely related to the overall determination of the tax base of IP boxes is the **treatment of resulting losses** based on the applicable net approach as well as the per-IP asset allocation of expenses and income. In order to ensure a proportionate treatment, IP boxes must be designed in such a way that it is not possible to offset initial and current losses against income taxed at the regular tax rate. However, the alignment of these initial R&D expenses is more complex, since these costs have been incurred in the past and will have been deducted from the regular tax base before the MNE applies for the IP box.

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[101] For an overview of designs of IP box before the modified nexus approach, see Evers (2015).

[102] For a definitional analysis of international tax arbitrage, see Ring (2002).

[103] If a per-IP asset allocation of expenses and income is not possible, MNEs are allowed to apply a product-based approach, i.e., product families (OECD, 2015b).

Although we observe international variations in the treatment of **current losses,** all regimes ensure that there is no asymmetrical treatment of these losses and beneficial income. The majority of countries allows to set off initial losses against ordinary income. To do so, there are three options: either a reduced value method (e.g., IE, IT, CY, MT, SK)[104], a benefit recovery method (e.g., FR, LU, MT, NL, PT)[105], or even a combination of both approaches (e.g., ES)[106]. Under the reduced value method, the taxpayer is not allowed to deduct the part of expenses which is proportional to the share of exempt qualifying IP income. The basic idea is to entirely avoid tax losses arising from IP box regimes. On the other hand, the benefit recovery method grants an initial offset at the regular corporate income tax rate, whereby subsequent profits have to be taxed regularly up to the amount of the initial loss offset. In Spain the respective treatment depends on the timing of losses: If losses occur after the preferential treatment of income, the reduced value method applies up to an amount equal to the previously exempted income. Excess (initial) losses can be set off against the regular corporate tax rate with a subsequent recapture by applying the benefit recovery method. In contrast, the separate loss method only allows to set off IP losses against qualifying IP income (e.g., BE, PL, LT, CH, and UK)[107]. Thus, IP losses cannot be used against ordinary income, even if there is no IP income against which to use the losses. This option usually provides an (un-)limited loss carry forward. Both approaches are in principal suited to ensure a proportional treatment of losses and income. Assuming that MNEs earn enough profits from other sources of income to use the direct loss offset, the separate loss method is less favourable from a taxpayer’s perspective, taking into account the time value of money. Offsetting the losses against regular taxed income results in an immediate offset of the losses and thus interest and liquidity benefits compared to the separate loss method. This advantage increases with the time lag between initial development costs and subsequently arising profits.

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[104] IE: Revenue Irish Tax and Customs (2020a); IT: IBFD (2021, sec. 1.9.4.3); CY: In line with the exemption of 80% of qualifying profits, only 20% of resulting losses can be surrendered to other group companies or be carried forward to subsequent years (Deloitte, 2021a); MT: Council of the European Union (2019c); SK: Council of the European Union (2018b).

[105] FR: Council of the European Union (2019a); LU: Council of the European Union (2018a); MT: Council of the European Union (Council of the European Union, 2019c); NL: IBFD (2021, sec. 1.9.7).; PT: Martins (2018).

[106] IBFD (2021, sec. 1.9.3.5 for Spain).

[107] BE: Any unused portion of the Belgium IP box deduction that is carried forward to a subsequent tax year will be added to a basket of tax attributes that are being carried forward (the Basket). In any subsequent tax year, no more than 70% of the taxpayer’s taxable income exceeding EUR 1,000,000 will be eligible for set-off against the aggregate tax attributes in the Basket that are being carried forward (Heyvaert, 2018); PL: Council of the European Union (2019d); LT: Council of the European Union (2019b); CH: Zürcher Steuerbuch (Merkblatt Patentbox, 2020); UK: Saffery Champness (2019).

In addition, the treatment of **historical expenses** (i.e., **initial losses**) incurred in connection with the qualified asset must also be considered, since these expenses reduced the tax base of the regular taxed profit as immediate expenses before the intangible asset has been created. To avoid tax arbitrage, these expenses have to be added to the regularly taxed profit and subsequently subtracted from the IP box tax base in the year in which the IP box benefit is claimed (BDI & ZVEI, 2016; Spengel, 2016). The recapture can take place in the form of capitalization or by means of the benefit recovery method. In the case of capitalization, the historical R&D expenses are fully added to the regular tax base and depreciated over the asset's useful lifetime (e.g., CY, HU, and SK)[108]. This mandatory periodical depreciation delays the tax deduction of R&D expenses and makes them less valuable from the taxpayer's perspective when considering the time value of money. Alternatively, IP box regimes that rely on the benefit recovery method apply the IP box tax rate only to the amount of income that exceeds the initial R&D expenditure. The remaining income is subject to the regular corporate tax rate (Evers, 2015; Felder, 2013). In line with the treatment of current losses, the majority of IP box regimes relies on the benefit recovery method which is more beneficial to the taxpayer due to the initial set off against the ordinary income (e.g., FR, IE, IT, LU, MT, NL, PT, ES, and UK)[109]. In addition, Belgium and Switzerland offer the option to choose between the two methods depending on the advantageousness in the respective situation.[110] Poland and Lithuania follow the separate loss method also for historical R&D expenditures. Thereby, these costs are treated as initial losses which have to be allocated against subsequent qualifying IP income.[111] The UK still follows the streaming approach.

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[108] CY: In Cyprus, the taxpayer may elect not to claim tax depreciation or only claim part of it in a certain taxable period. Unused tax depreciation can be carried forward and claimed as additional tax depreciation during the remaining useful life of the IP asset. This provides greater flexibility given the impact on the amount of notional interest deduction (limited to 80% of taxable income before notional interest deduction) and a limited loss carry forward of five years, see EY (2020a); HU: IBFD (2021, sec. 1.3.2); SK: Council of the European Union (2018b).

[109] FR: Council of the European Union (2019a); IE: Revenue Irish Tax and Customs (2020a); IT: IBFD (2021, sec. 1.9.4.3); LU: Council of the European Union (2018a); MT: Art. 6 (b)(ii) Legal Notice 208 of 2019; NL: IBFD (2021, sec. 1.9.7); PT: Art. 50a (7) Código do Imposto sobre o Rendimento das Pessoas; Martins (Martins, 2018); ES: In Spain expenses incurred in the creation of the assigned asset that have not been previously incorporated into the value of the aforementioned asset have to be deducted. Thus, we interpret this as an option to capitalize which is not mandatory (Art. 12 (3)(c) Ley del Impuesto sobre Socieadades); UK: HM Revenue and Customs (2021c, 2021b).

[110] BE: spread over a maximum of seven years (Heyvaert, 2018); CH: five years annual depreciation (Merkblatt Patentbox, 2020).

[111] PL: IP losses are always kept separate from the ordinary income even if there is no IP income against which to use the losses. However, a loss carryforward of five years is possible (Council of the European Union, 2019d); LT: In the report prepared by the Council of the European Union (2019b) the separate loss method is mentioned in case of losses. However, no further information is given on an initial recapture of historical expenses.

Table 13: IP box regimes in place in the European Union and selected other countries as of 2021

	Year[a]	Relief technique		Rate[b]		Tax base		
				CIT	IP	Expenses	Losses	Recapture
Belgium (BE)	2016	Notional Deduction	85	25.00	3.75	Net	Separate loss	Option [c]
Cyprus (CY)	2016	Partial Exemption	80	12.50	2.50	Net	Reduced value	Capitalization
France (FR)	2019	Preferential Tax Rate	.	33.00	11.70	Net	Separate loss	Benefit recovery
Hungary (HU)	2016	Partial Exemption	50	9.00	4.50	Net	N/A due to cap	Capitalization
Ireland (IE)	2016	Partial Exemption	50	12.50	6.25	Net	Reduced value	Benefit recovery
Italy (IT)	2015	Partial Exemption	50	27.70	12.975	Net	Benefit recovery	Benefit recovery
Lithuania (LT)	2018	Preferential Tax Rate	.	15.00	5.00	Net	Separate loss	Separate loss
Luxembourg (LU)	2018	Partial Exemption	80	24.94	4.99	Net	Benefit recovery	Benefit recovery
Malta (MT)	2019	Partial Exemption	95	35.00	1.75	Net	Reduced value/benefit recovery	Benefit recovery
Netherlands (NL)	2017	Preferential Tax Rate	.	25.00	9.00	Net	Benefit recovery	Benefit recovery
Poland (PL)	2019	Preferential Tax Rate	.	19.00	5.00	Net	Separate loss	Separate loss
Portugal (PT)	2016	Partial Exemption	50	21.00	10.50	Net	Benefit recovery	Benefit recovery
Slovakia (SK)	2018	Partial Exemption	50	21.00	10.50	Net	Reduced value	Capitalization
Spain (ES)	2018	Partial Exemption	60	25.00	10.00	Net	Reduced value/benefit recovery	Benefit recovery
Switzerland [c] (CH)	2020	Partial Exemption	90	21.10	9.18	Net	Separate loss	Option [d]
UK	2016	Notional Deduction	~47	19.00	10.00	Net	Separate loss	Streaming

Notes: [a] Year of implementation (of nexus); [b] The main rate includes the corporate income tax rate, surcharges levied on top of the corporate income tax rate, and other (local) income taxes. If no separate IP box rate is given, the effective IP box rate is the product of the main rate and the share of exempt income; [c] With a federal tax rate of 8.5%, a cantonal tax rate of 7% and a municipal multiplier of 129.01 for the canton Zurich as well as the mutual deductibility of federal and state tax, the effective IP box rate is as follows 9.18% (=0.085+0.07*229.01/100*(1-0.9))/(1+(0.085+0.07*229.01/100*(1-0.9)))); [d] Option to deduct immediately or to spread the recapture over seven periods (BE) or five periods (CH).

Table 14: Scope of qualifying IP and qualifying income as of 2021

	BE	CY	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	SK	ES	CH	UK
Scope of qualifying income																
Royalties	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Capital gains	✓[a]	Ex.	✓	Ex.	x	✓[a]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[b]
Sales income/notional royalties	✓	✓	x	✓	✓	✓	x	✓	✓	✓	✓	x	✓	x	✓	✓
Infringement	✓	✓	(x)	(x)	✓	(x)	✓	✓	✓	(x)	✓	✓	x	x	(x)	✓
Scope of qualifying assets																
Patents	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Supplementary protection certificates	✓	✓	✓	✓	✓	(✓)	✓	✓	✓	✓	✓	(x)	x	✓	✓	✓
Software copyright	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(x)	(x)
Other copyright	x	x	x	(x)	x	(x)	x	(x)	x	x	x	(x)	x	x	x	x
Trademarks	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Designs & models	(x)	x	x	(x)	x	✓	x	x	(x)	x	✓	✓	✓	✓	(x)	x
Utility models	(x)	✓	✓	✓	x	✓	x	✓	✓	✓	✓	✓	✓	✓	(x)	x
Plant breeders' rights	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	(x)	x	(x)	✓	✓
orphan drug designation	✓	✓	✓	✓	✓	(✓)	x	✓	✓	✓	✓	(x)	x	(✓)	(x)	✓
Secret formulas & processes	(✓)	x	✓	(x)	x	✓	(x)	(x)	(x)	x	x	x	x	✓	x	(x)
Know-how	x	x	x	(x)	x	✓	(x)	(x)	x	x	x	x	x	x	x	x

Notes: [a] Subject to a reinvestment condition; [b] Only proceeds related to sale of qualifying IP rights

In general, the implemented national IP boxes are accessible for resident entities which are subject to the national corporate income tax, as well as branches and PEs of non-resident entities which are subject to non-resident corporate income tax. Some countries, e.g., Italy, only grant the benefit to non-resident entities if the home-country has a double tax treaty in force with Italy and allows an effective exchange of information.[112]

Moreover, the IP box regimes generally distinguish between economic and legal ownership.[113] The Belgian IP Box has one of the broadest definitions, as it considers exclusive right holders as eligible in addition to legal and beneficial ownership. In contrast, the Dutch IP box restricts the access to the IP box regime to technical innovations that are developed under an approved R&D project that qualifies for a WBSO certificate. Usually, the economic ownership is sufficient in the majority of countries. This comprises an exclusive right (e.g., MT), a licensing rights (e.g., UK) or only temporary use of rights (e.g., PT).

Even though that all these national IP Box regimes have to comply with the mandatory nexus as of 2016, we still observe heterogeneous design features impacting corporate tax planning. In terms of effective tax rates, there has been no alignment since 2014: effective IP box tax rates range from 1.75% in Malta to 13.95% in Italy, well below the EU average of 21%. On the other hand, the introduction of the nexus has led to significant adjustments in the treatment of current expenses, initial losses, the scope of qualifying assets and income over time. Since 2019, with the adjustment of the French IP box, all European IP boxes have implemented the net approach. Likewise, tax arbitrage through the subsequent use of an IP box is now effectively prevented by considering initial losses in all European IP boxes. Yet, despite all these adjustments and restrictions on harmful tax competition, France, Lithuania, Portugal, and Spain exclude IP income from the internal exploitation or use, resulting in industry-specific distortions of investment location decisions. In summary, the introduction of nexus has generally increased the incentive for domestic companies to bear the full cost of development themselves where possible. Nevertheless, other companies also have an incentive to participate in the joint development of the intellectual property, at least through cost-sharing agreements, instead of buying or licensing what is created by others to benefit from the tax advantage.

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112 IT: IBFD (2021, sec. 1.9.4.3).

113 The economic owner can actually control, dispose and exploit the asset without being the legal owner (e.g., through purchase contracts), so that the ownership is assumed for tax purposes. BE: Delanoy et al. (2020); CY: EY (2016); IE: Revenue Irish Tax and Customs (2020a); IT: In Italy the box refers to the ownership as the right to economically exploit the qualifying IP asset (Gallo, 2018); MT: KPMG (2019); NL: Oosterhoff and de Nies (2016), Article 22ba National Tax Law; PL: Council of the European Union (2019d); PT: Art. 50a Código do Imposto sobre o Rendimento das Pessoas; UK: TWP Accounting (2019).

5.4. Methodology and procedure

5.4.1. Devereux-Griffith Methodology

To analyse the impact of the introduction of the nexus on firms' effective tax burden in IP box countries, we rely on the (prospective) effective tax rates methodology put forward by Devereux and Griffith (Devereux & Griffith, 1999, 2003; Evers et al., 2015). The effective tax burden measures allow for a better evaluation of the tax environment as they go beyond statutory corporate tax rates by incorporating further significant features of the underlying tax system, e.g., tax bases and tax incentives. Thus, this methodology is suitable to comprehensively point out the type and the extend of tax distortions on investment decisions and to highlight the impact of IP boxes (Jacobs & Spengel, 2000; Lammersen, 2005). The results enable us to analyse the impact of the recent developments on the influence of taxation on investment decisions, e.g., financing decisions, competition and distributional effects (Lammersen, 2005), on the tax attractiveness of locations and on international tax planning strategies.

The Devereux-Griffith methodology builds on a neoclassical investment theory of a perfect capital market. It distinguishes between marginal investments that just yield their cost of capital (CoC), i.e., the minimum real pre-tax return required by an investor compared to a given real post-tax return on an alternative investment (i.e., financial investment), and profitable investments that earn mobile firm-specific economic rents, i.e., a pre-tax return of 20%.[114] The CoC shows the impact of taxation on the scale of investments and a country's relative attractiveness for investment extensions compared to alternative investment locations. In contrast, the effective average tax rate (EATR) measures the change in the net present value (NPV) of a profitable investment caused by taxation. Since economic rents are limited, a company chooses the project with the highest NPV after taxes among two or more mutually exclusive projects (Devereux & Griffith, 1999). Hence, the EATR is the relevant measure if companies have to decide on the geographical allocation of economic returns in the course of investment location decisions (Devereux & Griffith, 2003; Devereux & Griffith, 1998).[115]

[114] For a detailed description of the model framework, see also Spengel (2003) and Spengel et al. (2021). We provide for a detailed description of the basic formulas and the extension for IP boxes of the Devereux-Griffith methodology in Appendix 19 as well as the underlying economic assumptions in Appendix 20.

[115] In empirical studies, researchers also focus on the EATR when focusing on FDI (Davies & Voget, 2009).

We restrict our analysis to the corporate level[116] and assume that the MNE generates sufficient other income to immediately benefit in full from any tax deduction. This assumption is most appropriate in large mature companies that generate income from other investment projects.[117] Besides country-specific tax information, the model rests on several important economic assumptions displayed in Appendix 20. The economic parameters are constant across all investments to isolate the effects of tax differences depending on the investment location.

5.4.2. Implementation of the nexus

We follow Evers et al. (2015) and consider a hypothetical R&D investment resulting in a self-developed patent to analyse the impact of the nexus on the effective tax burden of companies located in IP box countries. In doing so, we follow their assumption that all investment costs are current in nature (e.g., wages for R&D staff or materials).[118] Further, in line with previous literature, we acknowledge that the value of R&D expenditures is not realized immediately but accrues over several periods (B. H. Hall & Van Reenen, 2000; McKenzie, 2008).

The introduction of the nexus increases the tax location attractiveness of countries through the combined tax-beneficial treatment of IP income (i.e., preferential tax rates, partial exemption) and the treatment of the underlying R&D expenses (i.e., tax deductibility). When integrating the IP box into the model, the immediate tax advantage is generally expressed by replacing the regular corporate income tax rate with the IP box tax rate ($\tau > \tau_{IP}$) when calculating the after-tax NPV of the investment. Whereas previous literature on the modelling of IP boxes has assumed that all IP income is classified as tax-beneficial income (Evers et al., 2015; Pfeiffer & Spengel, 2017), we remove this assumption in the following. Due to the associated application of the substance requirement, the reduced IP box tax rate τ_{IP} can no longer generally replace the regular corporate income tax rate in the model.

Accordingly, we determine a modified IP box tax rate ($\tau_{IP\ nexus}$, where $\tau_{IP\ nexus} \leq \tau_{IP}$), which accounts for the nexus ratio $\varphi_{IP} = \frac{\min(1.3 \times E_{qualified}, E_{overall})}{E_{overall}}$. To do so, we first determine the overall tax burden T of a multinational company exploiting a patent investment:

$$T = \tau_{IP}(\varphi_{IP} \times I_{overall}) + \tau(I_{overall} - \varphi_{IP} \times I_{overall}) \quad (11)$$

[116] A consideration of personal tax characteristics of different shareholders regularly does not provide theoretical insights for profitable and discrete corporate investments (Devereux & Pearson, 1995; Lammersen, 2005).

[117] If, in contrast, the taxpayer is tax exhausted, the tax benefit associated with tax allowances is delayed. Thus, the NPV of tax allowances is lower and thereby the effective tax rates are higher as under the case of no-tax exhaustion (Devereux et al., 2002).

[118] Current expenses generally account for the largest share of R&D expenditures (Cameron, 1996; Leitner et al., 2011).

This overall tax burden comprises the share of tax-privileged income ($\varphi_{IP} \times I_{overall}$), subject to the IP box tax rate τ_{IP}, as well as a possible residual of non-tax-privileged income ($in_{overall} - \varphi_{IP} \times I_{overall}$), subject to the regular corporate income tax rate τ. This residual can arise due to partial non-compliance with the substance requirement, such that qualifying R&D expenditure does not equal total R&D expenditure ($E_{qualified} \neq E_{overall}$), e.g., due to outsourcing of R&D activities to affiliates.

We resolve Eq. (11) according to the implicit effective tax rate ($\frac{T}{I_{overall}}$) in order to determine the modified IP box tax rate under the nexus[119]:

$$\tau_{IP\ nexus} = (\tau_{IP} - \tau) \times \varphi_{IP} + \tau \tag{12}$$

Furthermore, the IP box affects the treatment of R&D expenses, i.e., the present value of tax allowances and of financing expenses.[120] Within our sample, all countries allow current R&D expenses accrued in the creation of a self-developed IP asset to be expensed immediately when they are incurred. In line with the nexus, all European IP box regimes apply the net income approach. Thus, the preferential IP box tax rate determines the value of the tax allowance of current expenses. For mandatory capitalization, we make the simplifying assumption that the immediate deduction and subsequent capitalization occur in the same period. Hence, the IP box rate is decisive for the NPV of the periodical depreciation allowances. Further, with respect to financing costs, i.e., (notional) interest expenses, the net income approach mandates that the tax shield is determined by the IP box tax rate.

Since the majority of countries does not require initial capitalization of development costs, a recapture mechanism of previous R&D expenditure is required to ensure equal treatment of income and (current) expenses. Otherwise, their asymmetric treatment results in a tax shield based on the regular taxed profit being greater than the tax burden of the income based on the modified IP box tax rate, so that $EATR \leq 0$. For countries that have a capitalization mechanism in place, we follow the procedure of an initial capitalization followed by periodical depreciation. If not stated otherwise in the national tax law, we assume a depreciation period of five years. However, if countries rely on the benefit recovery approach, i.e., taxing IP income up to the development expenses at the general corporate income tax rate, the preferential IP box rate does not necessarily apply immediately when IP income is earned. As noted by Evers et al.

[119] For a detailed calculation of the formula, see Appendix 21.

[120] It is further assumed that tax deductions are fully claimed immediately, both by the profitable investment and by offsetting against other positive income of the company.

(2015) this benefit recovery approach cannot be precisely modelled in the two-period framework of the Devereux-Griffith methodology.[121] We, therefore, follow Evers et al. (2015) and assume that the NPV of tax allowances is based on the preferential IP box rate and is best approximated by $A = \tau_{IP}$. Hence, MNEs having the option to choose between both approaches would always opt for the benefit recovery approach according to our model.

5.5. Main results

5.5.1. Effective tax burden of an investment in a (self-developed) patent (IP box regime)

To illustrate the impact of the nexus on the effective tax burden of firms in IP box countries, we focus our analysis on a domestic firm that develops and exploits the IP asset in the same jurisdiction. In doing so, we not only reflect the current incentive for firms to choose R&D locations that are fiscally attractive from the combined perspective of IP development and exploitation. Furthermore, this focus allows us to compare our results with the previous literature reflecting pre-nexus tax competition.

The first set of estimations presents the CoC in Table 15 and the EATR in Table 16 for both extremes in which the MNE bears either all qualifying costs or none at all. The latter represents our two baseline scenarios in which the domestic company generates revenue by licensing out a patent for which it has not incurred qualifying expenses to be eligible for the IP box. This scenario captures either the case where the company has purchased the relevant patent or where the company has fully outsourced the development of the patent to an affiliated company via contract R&D.[122] Since the company does not incur any qualifying costs for the development, it also does not qualify for a potential uplift under the nexus ratio. These results, and in particular the result of contract R&D, serve as a benchmark for the analysis of the impact of IP box regimes on the effective tax burden. This comparison of both extremes allows us to quantify the maximum tax benefit that a multinational could receive on a (self-developed) patent

[121] The two-period model according to Devereux &Griffith is unsuitable for modeling the threshold mechanism, since the income from IP does not exceed the current R&D expenses on the basis of the standard data set until the fourth period. This results from the comparison of revenues and R&D expenditures, which are assumed to be constant over time. The time effects are taken into account by discounting and generating the first payback in t_1, i.e., $I_{overall} > E_{overall} \leftrightarrow \sum_{t=1}^{T} \left(\frac{(p+\delta)(1+\pi)}{1+i}\right)^{t} > 1 \leftrightarrow T > 4$.

[122] R&D contracting arrangements are defined as the R&D activities performed by one party (the contractor) on behalf of, i.e., at the risk and for the account of, another party (the client). It is further understood that the client bears the risk for the contract research by performing, directing and controlling the R&D activity. This requires adequate resources, including sufficiently trained staff, to effectively direct and control the R&D work. Whereas the contractor receives remuneration, usually determined on a cost-plus basis, in return for its services, the client acquires legal and economic ownership of the intangible asset resulting from the R&D activity. For more details and practical examples, see OECD (2017a).

investment, based on existing IP box regimes. Further, we use the results of Evers et al. (2015) to quantify the changes in effective tax burden in the pre and post nexus era.

5.5.1.1 Marginal investment

We first present our results on the CoC, which demonstrate the effect of taxation on a marginal investment, i.e., an incremental corporate investment that just yields a rate of return on the initially invested capital that is sufficient to compete with an alternative investment. If the after-tax CoC is 5% and thus equal to the assumed real market interest rate of our alternative financial market investment, taxation has no influence on the corporate investment decision. Whereas a CoC below the real market interest rate indicates that taxation favours the respective corporate investment in a patent more than the alternative financial investment, which we assume as a benchmark.

The acquisition of patents results in a capitalization of the respective IP asset in all countries analysed, whereas MNEs are allowed to fully deduct the R&D expenses for contract R&D when incurred. The capitalization leads to a delayed recognition of expenses in the context of periodical allowances. Therefore, we observe capital costs above the 5% benchmark in the majority of countries considered, ranging from 5.29% in Poland to 6.51% in France. Only in Cyprus, Malta and Portugal is the existing notional interest deduction (NID) high enough to compensate for the distortion caused by capitalization, resulting in CoC that are significantly below the market interest rate (CY: 4.75%, MT: 3.60%; PT: 3.55%).

In contrast, the immediate deduction of R&D expenses under the regular tax system results in marginal investments being unaffected by taxation as it shields the marginal return from taxation. Thus, we observe for the majority of countries analysed a CoC of 5%, meaning that the MNE is indifferent between the corporate and the financial market investment. As a result, distorting tax effects are more pronounced, such as notional interest deductions (NID) as well as wealth taxation. While the CoC for NID-countries is up to 2.21 pp lower than for our benchmark investment, the Swiss wealth taxation on immovable assets, including self-developed patents, raises the CoC above the market interest rate, i.e., 5.18%. Thus, exerting a negative influence on the optimal level of investment activity.

Table 15: Comparison of the CoC for an equity-financed investment in a (self-developed) patent pre and post nexus (%)

	BE	CY	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	ES	SK	CH	UK	ø
Ex-ante nexus (2014)[a]																	
No qualifying expenses																	
Regular tax system	3.67	5.53	5.00	5.00	5.00	3.92	5.00	5.00	5.00	5.00	5.00	7.62	5.00	5.00	5.18	5.00	5.18
Full self-development																	
Self-development (IP box)	-1.88	5.10	0.44	2.86	.	.	.	5.23	5.00	5.00	.	3.57	1.53	.	.	5.00	3.67
Ex-post nexus (2021)																	
No qualifying expenses																	
Acquired patent	5.38	4.75	6.51	5.37	5.53	5.57	5.35	6.23	3.60	6.24	5.29	3.55	6.24	5.99	5.93	5.87	5.46
Outsourced to related party (regular tax system)	5.00	4.32	5.00	5.00	5.00	4.70	5.00	5.00	2.79	5.00	4.53	2.84	5.00	5.00	5.18	5.00	4.65
Full self-development																	
Self-development (IP box)	5.00	4.96	5.00	5.17	5.00	4.85	5.00	5.00	4.89	5.00	4.88	3.92	5.00	5.43	5.18	5.00	4.91
Change in generosity																	
Δ IP box	6.88	0.14	4.56	2.31	.	.	.	-0.23	0.00	0.00	.	0.35	3.47	.	.	0.00	

Notes: [a] For IP box countries the values for the situation ex-ante nexus introduction are taken from a previous publication by Evers et al. (2015). For non-IP box countries we estimated the CoC as of 2014. None of the non-IP box countries stipulates a capitalization of R&D expenses. The tax situation of an MNE without IP box benefit is given by the estimates under the regular tax system, which is equivalent to our scenario of fully outsourced R&D activity to a related party in the ex-post nexus period.
Source: own calculation

The comparison of our two baseline scenarios illustrates that the immediate deductibility of contract R&D expenses for tax purposes already represents a subsidization of R&D that does not exist in the case of acquisition. Only in Cyprus, Malta and Portugal is the existing NID high enough to compensate for the disadvantage of deferred depreciation. In the following, we, therefore, consider contract R&D as our benchmark to quantify the impact of IP boxes on the effective tax burden.

To quantify the maximum impact of an IP box on the effective tax burden of a patent investment, we next consider the other extreme, in which all qualifying expenses are borne by the company itself. Compared to the baseline scenario of contract R&D, the results show that the application of the IP box does not further reduce the CoC. This result is driven by the nexus, which prescribes a symmetrical treatment of current as well as historical expenses and costs. Therefore, companies can no longer reduce their tax base by deducting current as well as historical R&D expenses from the regular taxed corporate income tax base while the corresponding income is taxed at the favourable tax rate, as it was common in the past. In 2014, the mismatch of R&D expenses and IP income even results in a negative cost of capital of -1.88% in the Belgium IP box regime.[123] Thus, it is not surprising that countries applying an asymmetrical treatment of income and expenses in 2014, face large increases in the CoC in comparison to 2021.

On the contrary, the application of an IP box can be even detrimental to the company as IP-boxes can be associated with higher capital costs than under the regular tax system. This makes an investment in a fully self-developed patent relatively less attractive, both compared to the alternative financial market investment as well as contract R&D. This is mainly due to two reasons: While the increase in the Hungarian (+0.17 pp) and Slovakian CoC (+0.43 pp) is wholly driven by the mandatory capitalization to recapture historical R&D expenses, the Cypriot increase in the CoC (+0.64 pp) is a combination of the mandatory capitalization and a reduced value of the notional interest deduction. Due to the mandated net approach, MNEs have to allocate all financial expenses to beneficiary income. Thus, the value of the NID is determined by the effective IP box rate and this reduction increases the capital costs (IT: +0.15 pp, MT: +2.1 pp, PL: +0.35 pp, PT: +1.08 pp).

[123] For more details on the effective tax burden of IP boxes as of 2014, see Evers et al. (2015).

Our results are not driven by an equity investment, as shown by a sensitivity analysis based on debt financing (see Appendix 24).[124] Due to the deductibility of interest payments from the corporate tax base, we observe a lower level of CoC in the case of debt financing of up to 1.5 pp on average, depending on the scenario. As a result, in all cases analysed, the patent investment is treated more favourably for tax purposes than the alternative financial market investment. Consistent with the equity scenario, the immediate deductibility of R&D expenses makes it more advantageous on average for companies to develop the patent themselves rather than acquire it (ø-CoC 4.0% vs. 3.5%). Belgium is an exception, as a general investment credit applies to patent acquisition, which allows for an increased depreciation above 100% over the useful life. However, if one considers the IP box regimes, the CoC of a debt-financed investment approaches the market interest rate due to the lower NPV of the tax deduction. The value of this tax shield depends on the applicable tax rate, i.e., the regular corporate income tax rate or the IP box rate.

5.5.1.2 Profitable investment

In the following, we expand our analysis to the EATR as it is an important indicator of the attractiveness of investment locations in an international comparison. With respect to the acquisition of a patent, we observe an average effective tax burden of 18.77%, with EATRs ranging from 8.3% in Cyprus to 27.07% in France. In line with the evolution of the CoC, we observe that the immediate deductibility leads to a significant reduction in EATRs (-1.43 pp in BE to up to -5.36 pp in FR) compared to capitalization and subsequent periodic depreciation of R&D expenses. Still, our results show a wide dispersion of effective tax levels across countries for our baseline scenario of contract R&D, with a total spread of more than 15 pp. However, the relative location attractiveness of countries only slightly differs between both scenarios, in which the MNE does not incur any qualifying R&D expenses. Cyprus provides the most attractive location (6.41%), while France the least attractive (21.71%). We already observe, that the relative location attractiveness of countries is strongly correlated to the statutory tax rate, as the immediate deductibility of R&D expenses does not distort the corporate tax base. If we take the location decision as given, a MNE should rather invest in patent itself via contract R&D than in acquiring a patent. Thus, in line with the previous chapter, we treat the scenario of contract R&D as our baseline to quantify the impact of IP boxes on the effective average tax burden of a profitable patent investment. Within this

[124] Analogous to disregarding shareholder taxation, we do not consider the taxation of interest payments at the hand of the lender.

Table 16: Comparison of the EATR for an equity-financed investment in a (self-developed) patent pre and post nexus (%)

	BE	CY	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	ES	SK	CH	UK	ø
Ex-ante nexus (2014)[a]																	
CIT	33.99	12.5	35.41	19.00	12.50	31.29	15.00	29.22	35.00	25.00	19.00	30.00	30.00	22.00	21.15	21.00	24.5
IP box rate	6.80	2.50	16.76	9.50	.	.	.	5.84	0.00	5.00	.	15.00	12.00	.	.	10.00	8.34
No qualifying expenses																	
Regular tax system	21.11	11.69	26.56	14.25	9.38	19.76	11.25	21.92	26.25	18.75	14.25	31.68	22.50	16.5	16.57	15.75	18.64
Full self-development																	
Self-development (IP box)	-26.95	2.34	-6.41	-2.54	.	.	.	5.47	0.00	3.75	.	5.17	-2.95	.	.	7.50	8.34
Ex-post nexus (2021)																	
CIT	25.00	12.50	33.00	9.00	12.50	27.70	15.00	24.94	35.00	25.00	19.00	21.00	25.00	21.00	19.70	19.00	21.52
IP box rate	3.75	2.50	11.70	4.50	6.25	12.98	5.00	4.99	1.75	9.00	5.00	10.50	10.00	10.50	9.18	10.00	7.35
No qualifying expenses																	
Acquired patent	20.18	8.30	27.07	8.42	11.69	22.92	12.73	23.33	21.71	23.38	15.44	18.65	23.38	19.64	18.52	17.77	18.32
Outsourced to related party (regular tax system)	18.75	6.41	21.71	6.75	9.38	19.76	11.25	18.70	19.08	18.75	12.36	16.22	18.75	15.75	15.50	14.25	15.21
Full self-development																	
Self-development (IP box)	2.81	1.66	8.25	4.21	4.69	9.79	3.75	3.74	0.77	6.75	3.17	7.26	7.50	9.82	7.70	7.50	5.59
Change in generosity																	
Δ IP box	29.76	-0.68	14.66	6.75	.	.	.	-1.73	0.77	3.00	.	2.09	10.45	.	.	0.00	

Notes: [a] The values for the situation ex-ante nexus introduction are taken from a previous publication by Evers et al. (2015). For non-IP box countries we estimated the EATR as of 2014. None of the non-IP box countries stipulates a capitalization of R&D expenses. The tax situation of a MNE without IP box benefit is given by the estimates under the regular tax system, which is equivalent to our scenario of fully outsourced R&D activity to a related party in the ex-post nexus period.
Source: own calculation

scenario, the average effective tax burden is 15.21% and we observe three countries levying effective average tax rates below 10% (i.e., CY, HU, and IE). Among our comparison countries, only French MNEs face an EATR above 20% on their self-developed patent investment.

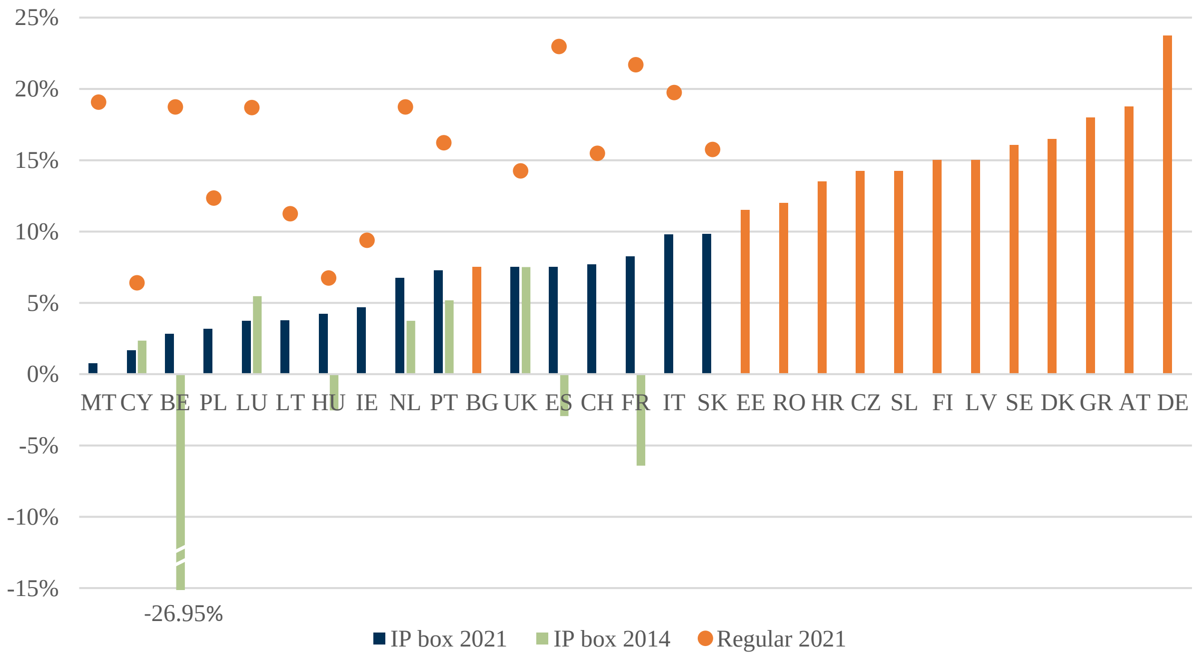
The application of the IP box further reduces the effective tax burden of profitable investment projects relative to the EATRs in the baseline scenarios. In contrast to previous literature, we do not observe negative EATRs (i.e., BE, ES, FR, HU in 2014) due to the mandatory net approach, which does not allow for an asymmetrical treatment of R&D expenses and IP income. Thus, MNEs cannot use these regimes to shelter (non-) IP income from taxation. Nonetheless, the IP box regimes offer a significant potential to reduce the EATR. In Malta corporations can reduce their EATR in the baseline scenario by 18.31 pp with behalf of the IP box regime, resulting in the smallest EATR in our sample and thus the most attractive location, at 0.77%. This huge reduction in EATR with more than 10 pp can also be observed in Belgium (-15.94 pp), Luxembourg (-14.96 pp), France (-13.46 pp) and Spain (-11.25 pp). These regimes have a high statutory corporate tax rate and thus, induce an accelerated leverage effect of the tax relief through the IP box regime.

In summary, we observe for eight countries EATRs below 5% (i.e., MT: 0.77%, CY: 1.66%, BE: 2.81%, PL: 3.17%, LU: 3.74%, LT: 3.75%, HU: 4.21%, IE: 4.69%), thus providing a very generous tax environment for in-house IP investments. While the effective tax burden in the larger economies in our comparison group is still comparatively moderate to high (IT: 9.79%, FR: 8.25%). With the exception of Italy and Slovakia, all other countries in our comparison group have more than halved their effective tax burden for a patent investment. Thus, it comes as no surprise that these two countries represent the least attractive investment location. However, they are closely followed by France, for which even a reduction of more than 10 pp is not enough to compete with the most attractive investment locations.

To put our results in a wider perspective, Figure 16 compares EATRs for a self-developed patent to the remaining EU Member States. IP box countries lead the country ranking. This is mainly because IP box regimes offer lower statutory tax rates than the regular tax rates in the other countries. Though, this is not always the case. For example, the IP box rate in France (11.7%), Italy (~12.98%) as well as Portugal and Slovakia (both 10.5%) are higher than the regular tax rate in Bulgaria (10%), being the only tax competitive EU country without IP box regime. Further, the comparison to 2014 highlights the increase in EATRs for most IP countries, except Cyprus and Luxemburg, after the implementation of the nexus approach.

For IP box countries, the dots in Figure 16 show the EATR under the regular tax system. The implementation of the IP box significantly improves their location attractiveness. In all countries the IP box regimes reduce the EATR below the EU-27 average EATR at 15.29%. Further, it shows that the majority of IP box countries, which would qualify under the regular tax system as moderate to high tax countries are as competitive as classical low tax countries in the EU, i.e., Eastern EU Member States as well as the Scandinavian countries.

Figure 16: Ranking of the EATRs for the EU-27 Member States, CH and UK as of 2021 (%)



Notes: Scenario of an equity-financed investment in a self-developed patent. The dots show the EATR under the regular tax system, without the application of the IP box regime.
Source: own illustration and calculation

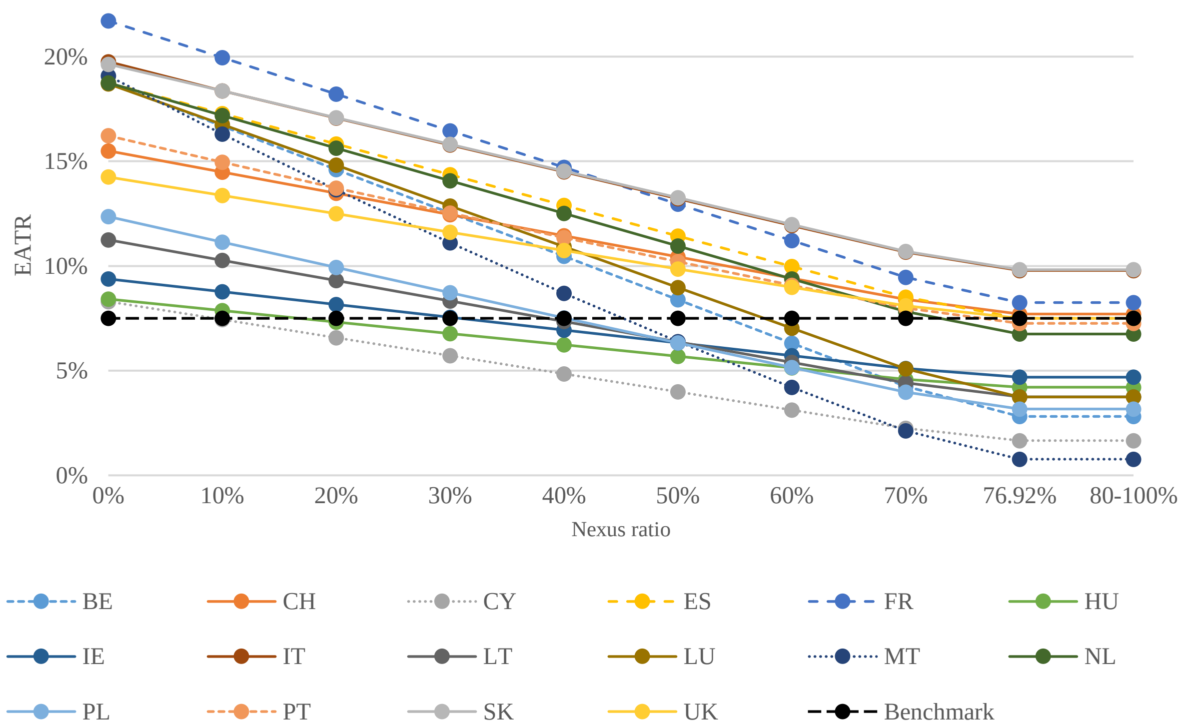
In summary, our results demonstrate that IP boxes substantially reduce effective tax rates. In addition, we show that the mandatory alignment of the treatment of expenses and income does not result in negative effective tax burdens and thus a subsidization of R&D investment. Further, it leads to the fact that the effective IP box tax rate (i.e., the amount of exempt IP income) becomes the decisive factor for determining the effective average tax burden. Our results apply strictly to the case of licensing income from the exploitation of patents. Nonetheless, to a large degree, they will equally apply to a wider scope than patents, e.g., software, embedded royalties. In calculating the precise effective tax burden, there would only be small differences, arising, for example, from different assumed economic depreciation rates.

5.5.2. Sensitivity analysis with respect to nexus ratio and way of financing

5.5.2.1 Nexus ratio

Besides the alignment of the tax treatment of R&D expenses and IP income, the implementation of a strict nexus requirement – the nexus ratio – significantly impacts the effective IP box tax rate. We therefore, examine this possible key driver of our result within a sensitivity analysis. If a company incurs less than 100% of the qualifying R&D expenses, it faces a proportional reduction in preferentially treated IP income, thereby increasing its effective IP box tax rate by the proportion of regular taxed income.[125] To partially mitigate this impact, as well as to not put certain groups of corporations at an extraordinary disadvantage, corporations qualify for an uplift of up to 30% on their qualifying expenses. Thus, they only have to incur 76.92% of qualifying expenses themselves to fully benefit from the IP box.

Figure 17: Sensitivity of the EATRs for the EU-27 Member States, Switzerland and UK on the Nexus Ratio



Notes: Scenario of an equity-financed investment in a self-developed patent. Our benchmark at 7.5% is based on the Bulgarian EATR for a self-developed patent, being the most tax competitive EU member state without an IP box regime. Further, we assume that all IP box countries opted for the IP box regime irrespective of the amount of qualifying income.
Source: own illustration and calculation

Figure 17 displays the evolution of the country EATRs by varying the nexus ratio. To better illustrate the relative location attractiveness of countries from a tax perspective, we refer to the

[125] A detailed derivation of the modified IP box tax rate is given in Appendix 21.

Bulgarian EATR for an in-house patent investment (= 7.5%) as a benchmark. Whereas none of the IP box countries could compete with the Bulgarian EATR if domestic MNEs do not incur qualifying expenses (nexus ratio of 0), we observe only four countries (i.e., CH, FR, IT, SK) with an EATR above our benchmark if the MNEs can make use of the full tax benefit.

For all other countries, we observe a broad range of the minimum required share of qualifying expenses to reach the target EATR of 7.5%. MNEs investing in Cyprus only need to reach a nexus ratio of 9.27%, as Cyprus levies a quite competitive EATR in a scenario without qualifying expenses, while competitors investing in the Netherlands and Portugal require a share of qualifying expenditures of more than 70% to be equally attractive (i.e., NL: 72.12%, PT: 73.32%). However, for several countries a share of less than 50% of qualifying expenses has to be incurred by MNEs to approach an effective tax burden of less than 7.5% (CY: 9.27%, HU: 16.81%, IE: 30.82%, LT: 38.46%, PL: 40.43%, MT: 46.70%). We present a detailed overview on the sensitivity of our EATRs based on the assumed nexus ratio in Appendix 23.

Due to the high sensitivity of the EATR to the nexus ratio, the relative location attractiveness between the countries considered may also change significantly. Whereas Malta is the most attractive location if one considers the full benefit of the IP box, it requires a share of more than 70% on qualifying R&D expenses to take over the top position from Cyprus. In case a Maltese MNE incurs less than half of the qualifying expenses itself, Malta is less attractive as a location for an equity financed patent than Poland, Lithuania, Ireland, Hungary and Cyprus. A similar pattern emerges for Belgium, which ranks initially third, but which again needs a nexus ratio of around 70% to be more competitive than the Eastern EU Member States and Ireland. The reason is the comparatively high regular corporate income tax rate, which is applicable on the proportion of IP income that does not qualify for the preferential tax rate. Taking into account that not all MNEs incur 100% of the qualifying expenses, a higher share of tax-exempt IP income is thus required to compensate for the high corporate income tax rate (e.g., MT: 90%). Thus, the position of a country relative to other IP box countries in terms of their effective tax burden is determined by the generosity of the implemented incentives themselves and the share of qualifying expenses but also by the level of taxation under regular income tax rules.

5.5.2.2 Debt-financing

Further, we show that our main results are not driven by the assumption on the type of financing. Due to the deductibility of interest payments from the corporate tax base, we observe on average a lower level not only for the CoC in the case of debt financing (up to 1.5 pp on average), but also for the EATR (-1.99 pp to -5.74 pp) depending on the scenario (Appendix 24).[126] The reason for this lower level in both effective tax rate measures lies in the deductibility of interest payments for debt financing, which reduces the tax base.

In line with our previously presented results the patent investment is treated more favourably for tax purposes than the alternative financial market investment in all cases analysed. Consistent with the equity scenario, the immediate deductibility of R&D expenses makes it on average more advantageous for companies to develop the patent themselves rather than to acquire it (ø-CoC 4.0% vs. 3.5%; ø-EATR 12.91% vs. 11.05%). Regarding the IP box regimes, the CoC of a debt-financed investment increases significantly and approaches the market interest rate due to the lower NPV of the tax deduction, as the value of this tax shield depends on the applicable tax rate, i.e., the regular corporate income tax rate or the IP box rate. In comparison to contract R&D, the EATRs further decrease if the MNE opts for the IP box (-7.14 pp on average).

5.5.3. Additional consideration of input-oriented R&D tax incentives

As shown in the previous subchapter, the nexus requires substantial R&D activity in the IP box location if MNEs are to enjoy the full benefit of the preferential regime. Thus, MNEs may also benefit from any existing input-oriented R&D tax incentives in those countries. These incentives include, e.g., R&D tax credits, accelerated depreciation or super deductions which are linked to R&D expenses and can reduce the costs of R&D activities significantly. Furthermore, these tax incentives can be considered as a tool for continually reducing the group's overall tax burden. Hence, countries could further increase their location's attractiveness for MNEs by providing both types of incentives. Therefore, we compare the effective tax burden of IP box regimes with R&D tax incentives as well as the possible combinations of those tax incentives in our selected IP box states.

We restrict our analysis to R&D tax incentives that are available to large firms, current expenses, and deducted from the corporate tax liability. Thus, we do not consider reductions in payroll taxes or social security contributions. Based on our selection criteria, we observe an input-oriented R&D tax incentive in all countries considered, except Cyprus and Luxembourg. In particular, five countries offer a super deduction in addition to the immediate deduction for R&D expenses (i.e., CH, HU, LT, PL, SK), while eight countries have enacted an additional tax credit (i.e., BE, ES, FR, IE, IT, MT, PT, UK). In our analysis, we exclude the Dutch R&D

[126] Analogous to disregarding shareholder taxation, we do not consider the taxation of interest payments at the hand of the lender.

tax credit as it is used to reduce the labour tax burden instead of the corporate income tax rate. For a detailed overview on the considered input-oriented R&D tax incentives, please refer to Appendix 22.

In Table 17 we provide a comparison of the effective tax measures of the baseline scenario on a fully self-developed patent with and without input-based R&D tax incentives. Consistent with the net approach according to the nexus, we allocate additional deductions of R&D expenses (i.e., super deductions) to preferentially taxed income. Thus, the super deductions cannot be used to reduce the regular tax burden of the MNE. As R&D tax credits are per definition independent of the applicable corporate income tax rate, we do not account for a net approach in these settings.

5.5.3.1 Marginal investment

In case of marginal investments, tax base regulations, like input-oriented R&D tax incentives, are key drivers of the effective tax burden and have a significant impact on its key indicator the CoC. Thus, we find that input-oriented tax incentives reduce the CoC to a greater extent in the context of a marginal investment compared to IP boxes. While the CoC ranges in case of an IP box from 3.92% in Portugal to 5.43% in Slovakia, in the case of input-oriented R&D tax incentives an expanded bandwidth of the results from -5.82% in Slovakia to 5.00% in Belgium is given. Further, we observe negative CoC for the offered tax credit in France, Ireland, Italy, Malta and Portugal, as well as for the super deduction offered in Lithuania and Slovakia.

In all countries, the combination of out- and input-oriented R&D tax incentives results in constant or even higher CoC relative to the separated consideration. The reasons for the reduction in the CoC are twofold: First, regardless of the applicable input-oriented R&D tax incentive, the CoC increase as the value of the tax shield of the initial deduction of R&D expenses is reduced. This is due to the fact that the value of depreciation is determined by the lower applicable IP box tax rate. In Cyprus, Hungary and Slovakia, this effect is amplified by mandatory capitalization. Second, by the application of the net principle, the value of the super deductions in Hungary, Lithuania, Poland, Slovakia, and Switzerland depends on the lower IP box rate, in line with the treatment of the initial deduction.

Table 17: Effective tax burden for an equity-financed (self-developed) patent under IP box regimes and R&D tax incentives as of 2021 (in %)

	BE	CY	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	SK	ES	CH	UK	ø
Statutory																	
CIT	25.00	12.50	33.00	9.00	12.50	27.70	15.00	24.94	35.00	25.00	19.00	21.00	21.00	25.00	19.70	19.00	21.52
CoC (%)																	
IP box	5.00	4.96	5.00	5.17	5.00	4.85	5.00	5.00	4.89	5.00	4.88	3.92	5.43	5.00	5.16	5.00	4.95
R&D tax incentive	5.00	4.32	-3.59	2.99	-0.81	-0.19	-2.18	5.00	-2.89	5.00	0.13	-5.22	-5.82	-1.78	3.09	2.35	0.34
both incentives	4.43	4.96	-1.86	4.39	-0.43	0.62	2.86	5.00	-0.26	5.00	3.81	-3.51	0.23	-0.65	4.94	2.62	2.01
EATR (%)																	
IP box	2.81	1.66	8.25	4.21	4.69	9.79	3.75	3.74	0.77	6.75	3.17	7.26	9.82	12.56	7.60	7.50	5.90
R&D tax incentive	18.77	6.41	-8.82	-2.41	-16.06	2.13	-19.28	18.70	0.59	18.75	-5.46	-11.39	-26.99	-6.69	7.11	3.54	-1.07
both incentives	0.09	1.66	-22.27	0.46	-20.75	-8.39	-6.43	3.74	-24.53	6.75	-1.89	-24.05	-13.49	-17.94	6.61	-3.21	-7.73

Notes: In CY, LU and NL the R&D scenario captures the baseline scenario without any R&D tax incentive. We do not consider the Dutch R&D incentive as it is applicable against payroll taxation instead of the corporate income tax.
Source: own calculation

5.5.3.2 *Profitable investment*

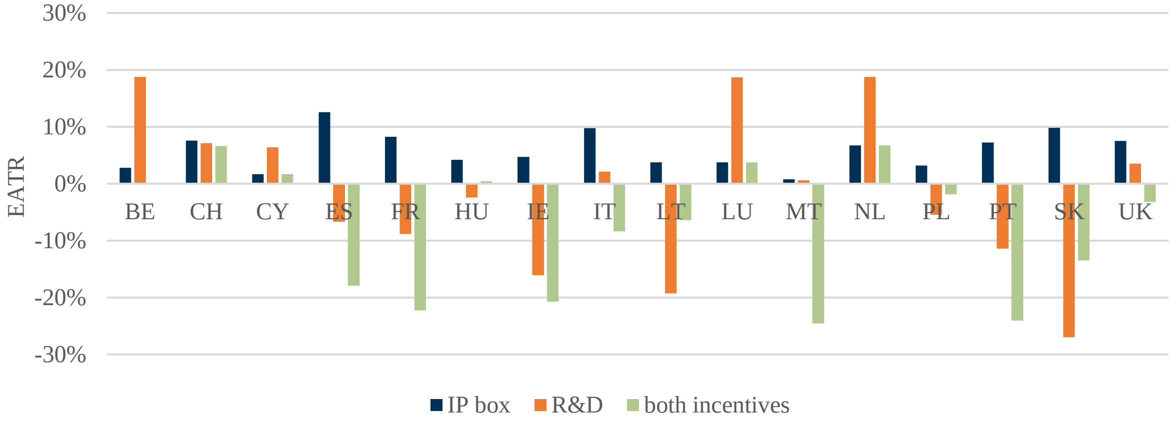
Secondly, as depicted in Table 17, the application of (input-oriented) R&D tax incentives results in a significant reduction of the EATR as opposed to the regular tax system and, in general, also with respect to the application of IP box regimes.[127] Moreover, we observe negative EATRs in eight countries which imply that an investment's post-tax NPV is higher than its pre-tax NPV, or respectively, a subsidy for the investment is offered. Regarding the interaction of the two leverages of the tax relief, our results show that with an increase in profitability of the investment, tax base adjustments are less decisive (respectively, the more critical is the applicable tax rate). R&D tax incentives offer a more significant potential to reduce the effective tax burden of an investment in a self-developed patent, which is in line with the goal to decrease the costs of conducting R&D. This creates an incentive for MNEs to accrue sufficient other income in the (input-oriented) R&D tax incentive country to fully make use of the tax benefits. Thus, there is an incentive to co-locate R&D activities and the exploitation of the resulting IP asset as well as other kinds of activities which are taxed at the regular tax rate. The negative EATRs indicate that companies may be able to shelter non-R&D income from taxation by investing in R&D in the half of our comparison countries.

In Figure 18, we present our estimates of the effective tax burden resulting from combining both types of R&D tax incentives, i.e., input-based incentives and IP boxes. Based on the design of the input-oriented R&D tax incentives, we observe opposing effects in the EATR in combination with IP boxes. On the one hand, allocating the super deduction to preferentially treated IP income due to the net approach reduces the value of the tax shield, leading to higher EATRs compared to the case of considering R&D tax incentives only. Nonetheless, the combination of the super deduction and the IP box still leads to slightly reduced, negative EATRs in Lithuania, Poland, and Slovakia. In particular, in Lithuania and Poland our results present an upper bound due to the applicable separate loss method. If MNEs located in these two countries do not generate sufficient other eligible IP box income from other IP investments, the EATR would increase as the full benefit of the combined tax incentives could only be realized in the future. Switzerland, which also relies on a super deduction, shows an opposing effect of the combination of both incentives. Here, the EATR further reduces by opting for the IP box. This is driven by the design of both Swiss R&D tax incentives: Since the R&D tax incentives are only applicable at the cantonal and not at the federal level, their general impact is limited. This is particularly evident in the case of the super deduction. Hence, the reduction

[127] In CY, LU, and NL, no R&D tax incentives are modeled.

in the Swiss EATR is driven by an overcompensation of the reduced value of the super deduction by the tax rate reduction.

Figure 18: Sensitivity of the EATRs for the EU-27 Member States, Switzerland and UK to R&D tax incentives



Notes: Scenario of an equity-financed investment in a self-developed patent. In CY, LU and NL the R&D scenario captures the baseline scenario without any R&D tax incentive. We do not consider the Dutch R&D incentive as it is applicable against payroll taxation instead of the corporate income tax.
Source: own illustration and calculation

On the other hand, we observe an accelerated affect for R&D tax credits in a combination of both approaches. In combination the EATRs further reduce by on average -13.39 pp compared to the situation of R&D tax incentives only. However, we observe strong variations in the EATR reduction between the countries considered (i.e., MT: -25.12 pp vs. IE: -4.69 pp). Also, particularly striking are the extremely low EATRs of less than -20% in France, Ireland, Malta, and Portugal. These values result from the interaction of the low IP box tax rates (FR: 10%, IE: 6.25%, MT: 1.75%, PT: 10.5%), i.e., the resulting small tax liability, and the relatively high tax credits (FR: 30%, IE: 25%, MT: 25%, PT: 32.5%).

Summarizing, we show that especially R&D tax credits are well suited for a combination of IP boxes to reduce the overall effective tax burden on MNEs for a self-developed patent investment. Thus, countries providing both tax incentives are the most attractive investment locations in our comparison group.

5.6. Conclusion

In this paper, we examine in qualitative and quantitative terms the IP boxes in Europe in the light of the changes through the nexus. Concerning the qualitative evaluation, the aligning character of the nexus has been merely successful in enforcing the net approach and reducing the scope of beneficially treated IP assets that are not considered as predominant tax evasion vehicles. Thus, the key characteristics of IP box regimes that have been used for aggressive tax planning are theoretically abolished. However, the states still have leeway with regard to the design of IP box regimes and thus, the extent of tax benefits. One major difference that impacts the scope of application is the definition of embedded royalties as qualifying expenses as the non-recognition can lead to discrimination of certain industries that only make use of royalties within the internal production process (e.g., automobile). Furthermore, as our results show the treatment of losses still widely differs across regimes and impact on the effective tax burden. Loss treatment approaches that limit the set off to the reduced tax IP income (e.g., separate loss approach) lead to a smaller tax reduction effect compared to unlimited offsetting against the corporate tax burden.

Regarding the quantitative research, we incorporate the nexus into the existing measure of effective tax rates according to the Devereux-Griffith methodology. Our results demonstrate that even after the introduction of the nexus a large reduction in the EATR is possible. Nonetheless, we find that the nexus, in accordance with the policy intention of preventing BEPS concerns, effectively prevents excessive reductions of MNEs' tax burden. Therefore, we show that the post-nexus IP box regimes decrease in CoC and EATR compared to the countries' regular taxation but without producing negative tax burden measures. Thus, the effect of this output-oriented tax incentive on the effective tax burden is mainly driven by the share of tax-exempt income.

Moreover, the location attractiveness ranking of IP box regimes in terms of effective tax burdens is highly sensitive to the nexus-ratio, whereas the position is determined by the generosity of the implemented incentives themselves, the share of qualified expenses, and the level of the regular corporate income taxation. Besides already existing tax instruments such as the NID, which should eliminate the debt-equity bias and fits R&D intensive investments, predominantly financed by equity, we also examine the combination with other input-oriented R&D tax incentives. Even though the IP tax planning changed during the last decades, the combined out- and input-oriented tax incentives can be seen as attractive measures for reducing MNEs' tax liabilities and thus, increase the location attractiveness. Our results undermine this statement as negative EATRs are given in the scenario of a combination of incentives in 10 out of 16 states. Moreover, we show that especially IP boxes combined with R&D tax credits are suited to reduce the overall effective tax burden of MNEs for a self-developed patent. Thus, the parallel application of the IP box decreases the beneficial effect in case of the first group of tax incentives.

Regarding our results, we summarize that IP boxes are still a decisive factor of a country's location attractiveness under tax considerations for MNEs but not at the cost of aggressive tax subsidies. In the future, the invention and development of service and production technologies like artificial intelligence will not only impact the scope of application of IP box regimes but also the location-related organization of MNEs. Thus, policy makers should carefully monitor the technological developments in order to maintain the fairness in international tax planning.

6. How does the Evolution of R&D Tax Incentives Schemes Impact Their Effectiveness? Evidence from a Meta-Analysis[128]

6.1. Introduction

It is well-known that firms under-invest in R&D activities due to the fundamental uncertainty involved and the limited appropriability of knowledge (Arrow, 1972; Nelson, 1959). To incentivize private R&D expenditures, numerous countries have combined different innovation policies (i.e. R&D subsidies and grants, public procurement) with fiscal ones. In this regard, reducing the cost of R&D by introducing R&D tax incentives (e.g. corporate tax reduction following an R&D investment) has become a widespread instrument to stimulate private R&D (Cabral et al., 2021). Doing so rewards firms that bear the costs and the uncertainty characterising R&D efforts. Early evidence of R&D tax incentives, especially from the USA (Berger, 1993; B. H. Hall, 1993; Swenson, 1992), acted as proof of concepts and eased the adoption of R&D tax incentives across a large number of countries (31 today, Cabral et al., 2021). However, the results found in the literature remain ambiguous: Berger (1993), Hall (1993), Swenson (1992), Agrawal et al. (2020), Guceri and Liu (2019) find a strong and significant effect of R&D tax incentives on R&D spending in the short run while Labeaga et al. (2014), Thomson (2010), Mulkay and Mairesse (2013) find no effect with a few positive results in the long run (Labeaga et al., 2021; Mulkay & Mairesse, 2013). Thomson (2013) puts to the front that the heterogeneity of R&D tax incentives implemented across countries is likely to explain the contrasting results found in the literature.

We propose to investigate the role of R&D tax incentives designs in a meta-analysis framework to explain the discrepancies found across studies. We articulate dedicated variables characterising the design of R&D tax incentives with the set of micro-econometric results found in the two streams of literature composing the empirical evaluations of R&D tax incentives on R&D spending. By doing so, we supplement the meta-analysis of Castellacci and Lie (2015) by providing an alternative source of explanation about the heterogeneity found across studies.

[128] This chapter is joint work with Florence Blandinières. We thank three anonymous reviewers for their constructive comments on the previous version of the study. We also would like to thank Christian Rammer, Christoph Spengel, Bernd Weiß, Jonas Hasler, Florence Wider-Kinne, Markus Trunschke, Moritz Lubczyk for their support. An earlier version the study was presented at different workshops and conferences: ZEW-WEI 2019, DRUID19, CONCORDi 2019, MAER-Net Colloquium 2019, TPRI Brown Bag, joint Walter Eucken Institute and ZEW workshop. The authors would like to thank the related discussants and participants. We gratefully acknowledge support from the MannheimTaxation Science Campus, funded by the Leibniz Association, the state of Baden-Württemberg, and the participating institutions ZEW and the University of Mannheim on the initial version of the study.

Besides an update of the literature, we further enhance the comparability of the estimates by transforming them through a common metric (e.g. Partial Correlation Coefficients) and applying more conservative inclusion criteria. We perform our analysis on micro-estimates exclusively reflecting the effect on R&D spending evaluated in a given country and period in order to isolate the characteristics of the underpinning R&D tax incentives scheme.

We find that on average R&D tax incentives stimulate private R&D spending even if their effects vary over time. Overall, our analysis underlines that recent estimates find a decrease in the magnitude and significance level of the relationship between R&D tax incentives and expenditures. This trend is reflected by a change in the base definition: incremental base estimates show higher results than hybrid and volume-based ones. Those are less likely to substantially affect R&D spending than incremental estimates. Shifting the base definition towards a volume definition seems to go with lower effectiveness than the introduction of a volume-based scheme. The latter is consistent with our framework, in which we stress the importance of a clear and stable scheme to reduce the administrative costs of claiming. In our robustness checks, we find that volume-based estimates have a higher effect when they combine targeted small and medium-sized enterprises (SMEs) schemes with an immediate refund rule, or a specific refund rate. Results are more ambiguous regarding the type of tax incentives (enhanced deductions vs. tax credits) depending on the reference category taken into account. Finally, our results show that governments can increase the predictability of the amount of foregone revenue through the use of a pre-approval process or caps without a detrimental effect on the average effectiveness.

On the whole, our analysis stresses the importance of creating and sustaining a clear institutional framework to enhance the predictability of the firm's financial returns from the tax claims. Doing so raises the firms' incentives to claim R&D deductions in the short run. The paper is structured as follows: Chapter 6.2 provides the rationale behind the different tax incentives schemes, chapter 6.3 develops the empirical strategies and the meta-regression approaches used, chapter 6.4 presents the results performed on the structural and direct estimates. Chapter 6.5 discusses the previous results by replicating the analysis with the best approaches across the two samples as robustness checks. Chapter 0 summarizes the main results, limitations, and further avenues.

6.2. Tax incentives: theory and empirical evaluations

R&D tax incentives constitute an important indirect policy instrument to support private research and innovation efforts. It relies on the following theory: the intersection of a downward sloping demand for R&D, and an upward sloping supply of R&D inputs determines the optimal level of private R&D. Ceteris paribus, R&D as an economic input becomes less expensive via the reduction of the corporate tax burden linked to R&D tax incentives, as it stimulates firms' R&D spending (B. H. Hall, 1993). The reduction in corporate tax liability creates a tax shield, which increases with the amount of eligible R&D expenditures defined by the tax law.[129] The main advantages of R&D tax incentives lie in their stability and predictability. Contrary to subsidies, they do neither require a budget, nor administrative units to monitor their use, and are independent of political agendas (Bozeman & Link, 1984). Moreover, R&D tax incentives reward innovative actors and reduce the risk of "picking losers" (Bozeman & Link, 1984; Dechezleprêtre et al., 2016). Firms receive financial rewards after and not before conducting R&D activities. As it will become evident in the following subchapters, firms' incentives differ a lot across schemes.

6.2.1. Evolution of tax incentives over time

The design of R&D tax incentives reflects the approach that governments decide to develop in order to tackle a changing global innovation environment. In the 1980s, governments heavily relied on R&D subsidies as a key mechanism to sustain innovation efforts. In this context, direct governmental interventions were justified by the need to sustain domestic firms' innovation efforts in an environment that became increasingly internationally competitive (see Spencer & Brander, 1983). Globalization brought additional opportunities and pressures for domestic firms in improving, or maintaining their position in international markets. The rise of the Asian Tigers over this period provided the conditions for a boost in innovation efforts in high tech sectors. In that sense, global R&D competition fell in line with Arrow's argument according to which competition provides incentives to efficiently organize production, lower costs, and stimulate innovation (Arrow, 1972). Over this decade, the first tax incentives designs had mostly an incremental base with carry-forward rules without differentiating between SMEs and large firms.

In the 1990s, capital mobility intensified as a result of financial globalization (Rodrik, 1998). International organizations, such as the World Trade Organization (WTO), played a leading role in this process. In this respect, the accession of China to the WTO marked a turning point in the nature of the international competition in high tech sectors. While firms at the frontier

[129] The definition of eligible R&D expenditures differs among countries. Many countries refer to the OECD's Frascati Manual which sets the benchmark for identifying R&D activities. For further details of the Frascati Manual, see OECD (2015c).

benefit from this trade liberalization, laggards tend to suffer from an increase in international trade (Shu & Steinwender, 2019). The heterogeneity of this trade liberalization (see Aghion et al., 2005, for a theoretical explanation) reduced on average the incentives to innovate. To lower costs, an increasing share of manufacturing activities has been relocated from the Western world to eastern or Asian countries. This trend has focused the competition on lowering costs more than enhancing quality and has put governments under pressure to increase their location attractiveness by reducing the overall tax burden (Overesch & Rincke, 2011). This changing set of incentives at the international level combined with the increasing competition to attract capital investments creates the prerequisite for the development of tax competition. This has been translated by a decreasing trend in corporate income taxes to attract high tax income activities related to high tech sectors, e.g. "smart tax competition" (Bräutigam et al., 2018). R&D tax incentives were then used as an additional tool to maintain innovation efforts in a given country.

6.2.1.1 Types of R&D tax incentives: tax credits and super deductions

The most popular types of R&D tax incentives are tax credits, directly followed by super deductions (Straathof et al., 2014). Super deductions reduce the corporate taxable income (e.g. by more than 100% of eligible R&D expenditures) while tax credits allow firms to deduct a given percentage of their R&D expenditures from their corporate tax liability. These differences in the source and timing of the tax relief impact its predictability. With regard to tax credits, firms only need to know the planned R&D spending and the applicable incentive rate to determine the financial benefit. In contrast, firms need additional information on their overall expected tax position at the end of the year to estimate the financial benefit of super deductions.[130] Therefore, R&D tax credits are easier to forecast than super deductions, which eases their integration within firms' R&D investment decisions (OECD, 2003). This argument has motivated countries to shift from super deductions to tax credits, such as the British example in 2015.[131] The predictability of the financial return of tax incentives is further influenced by

[130] The financial benefit of super deductions is the product of the additional deduction of taxable income and the applicable marginal corporate income tax rate. The marginal tax rate is a result from several factors beyond R&D expenditures which makes it difficult to plan over the long-term. In case of losses a firm's applicable tax rate is zero in the year the loss is incurred and, potentially, future years.

[131] R&D tax credits do not reduce the reported profitability of firms (reflected in pre-tax earnings). A public consultation highlighted that especially multinational firm's value the higher visibility of R&D tax credits, as group capital is typically allocated based on firm performance, measured by pre-tax earnings (HM Treasury, 2012).

the base definition, and the refund rules. Those determinants are discussed in the following subchapters.

6.2.1.2 Bases of R&D tax incentives: Incremental, volume or hybrid R&D tax incentives

As mentioned in subchapter 6.2.1, the initial R&D tax incentives schemes were mostly incremental. An incremental base implies that only firms performing R&D expenditures above a given threshold are eligible to claim R&D tax incentives. By the same token, it lowers the risk of relabelling R&D expenditures as it is not sustainable to over- or underestimate R&D expenditures in the long term (Larédo et al., 2016).[132] The eligibility threshold is usually measured via the averaged past R&D expenditures. Since this base only rewards additional R&D spending, it reduces the risk of subsidizing windfall gains for existing R&D investments (Bozeman & Link, 1984). However, the reliance on a pre-defined threshold is a major drawback: the moving average of past R&D spending discourages firms to persistently increase R&D activities as current R&D expenditures raise the future threshold.[133] This base definition tends to distort firms' R&D planning, as firms develop strategies to maximize their tax gains by gradually increasing their R&D investment via stop and go procedures instead of doing a single large investment (Correa et al., 2013; Straathof et al., 2014). The complexity of incremental tax incentives increases the compliance costs for both governments and firms, who could even refrain from participating if the application costs are perceived to be higher than the uncertain benefits.

The drawbacks of incremental bases listed above motivated the shift towards a volume-based definition by considering the total amount of current R&D expenditures. By doing so, governments decrease the administrations' and the firms' compliance costs related to tax incentives (Larédo et al., 2016; Spengel, 2009). Likewise, the financial benefits of tax credits are more generous and predictable from the firms' perspective. In theory, more firms should hence claim R&D tax credits under a volume-based scheme than in the case of incremental ones. This is particularly true for SMEs with less persistent R&D efforts as they are more cash constraint than larger firms (stronger market failure). The downside of this design is that it leaves more room for R&D expenditures to be relabelled if applicants become more familiar with the application procedure. In addition to this, there is an increased risk of subsidizing infra-

[132] However, even within incremental designs there is the risk of relabeling if uncertainty remains in the definition of qualifying R&D expenditures (B. H. Hall, 2001; Laplante et al., 2019) and if there is no direct connection to previous R&D investments in the base definition.

[133] An alternative is the introduction of base amounts which are unrelated to current spending (e.g. the current US incremental tax credit), increasing the risk of relabeling.

marginal R&D projects, which would have been conducted even in the absence of the R&D tax incentives. To enhance extra R&D efforts, governments can extend volume bases with an incremental component (e.g. hybrid bases). The combination of both base components aims at benefiting from the best of both worlds (e.g. low application costs, and incentives to stimulate incremental R&D expenditures) but comes at the price of increasing the complexity of the scheme. This complexity and the higher threshold in R&D spending, which is inherent in hybrid as well as incremental R&D tax incentives, represents a disincentive for firms to apply (Appelt et al., 2016; B. H. Hall, 2019).

6.2.1.3 Predictability and generosity schemes from the firms' perspective

Additional features such as refund rules, caps, and pre-approval affect the predictability and generosity of R&D tax incentives, and therefore, their overall effectiveness. One reason to explain the popularity of volume-based schemes lies in their attempt to better target SMEs. R&D tax incentives are by definition addressed to firms with sufficient tax liabilities, creating serious disparities between large and small firms in their capacity to benefit from this type of policy. As highlighted in Bozeman & Link (1984), new firms may not be profitable and hence, do not have enough tax liability in the early years in which they commercialize their first products. Moreover, the risks involved in R&D activities may imply that large firms are more equipped than SMEs to survive in the subsequent years to reap the tax benefits of innovation activities (Bozeman & Link, 1984). To minimize these disparities between large and small firms, governments can use two different refund options: carry forwards and immediate cash refunds. Nowadays, most governments rely on carrying forward rules to benefit from unused R&D tax credits in future periods.[134] As a result, firms do not lose the tax benefit due to insufficient tax liability over a given year. However, since there is a considerable time lag between R&D investments and expected revenues, small firms are more likely to benefit from an immediate cash refund than carry-forward rules. Immediate refund rules work like a direct subsidy by relaxing the financial constraints, typically higher among SMEs (Elschner et al., 2011).[135] In addition to this, an immediate refund increases the predictability of the tax benefits, helping its consideration within R&D investment strategies. Schemes without such refund rules are less likely to be efficient. Even if firms are in principle eligible (based on their R&D spending), they are less likely to claim a reduction of their tax burden if they do not have enough tax liability (B. H. Hall & Van Reenen, 2000). Governments can also decide to target SMEs

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[134] This treatment is equivalent to loss-carryforwards in case of super deductions.

[135] Agrawal et al. (2020) show that SMEs are especially responsive to cash refunds as these companies face limited amounts of free cash flow or do not have enough tax liability to make use of the R&D tax credit.

directly, considering that they are less likely than large firms to benefit from R&D tax incentives. To do so, governments could restrict the aforementioned cash refund to SMEs only, or simply provide a higher funding rate than the one for large firms. With higher financial incentives, SMEs should be more likely to bear the initial application costs for R&D tax incentives and to start participating regularly.

6.2.1.4 Predictability for governments

While R&D tax incentives represent an instrument to sustain innovation efforts, they also imply a large amount of foregone revenues for governments. To forecast this amount, governments can introduce different rules to limit or monitor firms' claims and to plan expenditures accordingly. A first approach consists of introducing a cap in the amount of the possible tax benefit per company. Doing so applies the binding constraints on the largest players but does not legally discriminate across actors. However, such a limitation can severely reduce the incentives to expand innovation activities, especially for firms that already spend a lot on research or are approaching the cap (Appelt et al., 2016). Various countries that have implemented such caps seem to reconsider the optimal level to boost incentives for medium-sized companies (A. Agrawal et al., 2020; Cappelen et al., 2012; Mulkay & Mairesse, 2013). An alternative to closely monitoring the amount of foregone tax relies on a pre-approval of the eligibility of the R&D expenditures. Before being able to claim R&D tax deductions, firms have to apply to document the nature of their R&D activities to be considered as eligible. Pre-approval increases the predictability of the amount of eligible R&D expenditures for the government and for the claiming companies as well. Nevertheless, pre-approval can be a costly process for both parties to audit the relevancy of the project submitted. As previously seen, the interactions of several tax incentives features are likely to provide different incentives to firms, and in turn, affect the magnitude and significance of the results found in the literature. Our set of variables takes into account this diversity across our samples.

6.2.2. Evaluating the impact of R&D tax incentives on R&D demand

Introducing a tax incentive means changing the relative costs of conducting R&D which should increase firms' incentives to intensify the R&D activities conducted. This type of evaluation is called input additionality, in the sense that it looks at an increase in R&D as an input for innovation. We can distinguish two main approaches to evaluate the impact of tax incentives. The first approach being structural and the second direct. In the former, the impact of tax incentives is captured via a parameter, the user cost, which takes into account the reduction of R&D costs. Doing so directly links the cost and demand for R&D and is typically measured via an elasticity (e.g. log-log specification). Thus, structural approaches measure the percentage change in R&D resulting from the tax relief for every percentage change in its after-tax price ("the user cost of R&D"). The simplest version of user cost is defined as: $UC_{i,t} = \frac{1-A_{i,t}}{1-\tau} * (r_{i,t} + \delta)$, where r refers to the real interest rate, δ to the depreciation rate of knowledge, τ to the corporate income tax, and A to the net present value of capital allowances and deductions which reflect the reduction in tax liability for each dollar used in R&D. In general, structural estimations can be summarized as follows:

$$R\&D_{i,t} = \beta_0 + \beta_1 * UC_{i,t} + \beta_2 * X_i + \beta_3 * T_t + \epsilon_{i,t} \tag{13}$$

where X_i refers to firm fixed effects and T_t to year fixed effects (in a panel setting) and $UC_{i,t}$ to the user costs of R&D for a given firm (i) and period (t). The coefficient of interest is β_1, estimating the R&D price elasticity. Estimations may vary if the researcher uses cross-sectional data, relying on other firm controls than in a fixed effect approach. While very appealing to economically interpret the impact of tax incentives on firms' R&D demand, structural approaches suffer from endogeneity and selection. For this reason, authors increasingly rely on direct approaches (e.g. difference-in-difference (DiD), regression discontinuity design (RDD) and quasi-experiments). While selection is not always tackled, the direct approach framework better tackles endogeneity by exploiting variations from the eligibility, or from the tax scheme change criteria to assess the actual impact of tax incentives on R&D demand. In the literature concerning direct approaches, R&D expenditures are directly regressed on a variable that serves as an indicator of the strength of R&D tax incentives ($D_{i,t}$) firm (i) faces in period (t). Whereas most authors rely on a binary indicator ($D_{i,t}$) either reflecting the general eligibility for the tax incentive or the actual treatment of the firm (e.g. applied for tax incentives, received or eligible tax incentives), some authors use the absolute firm-specific amount of R&D tax incentive received. Most of the evaluations in this stream of literature relies on a DiD framework to estimate β_1 as input additionality by comparing the effect across a treatment and control groups.

$$R\&D_{i,t} = \beta_0 + \beta_1 * D_{i,t} + \beta_2 * X_i + \beta_3 * T_t + \epsilon_{i,t} \tag{14}$$

The interpretation of β_1 from Equation (14) is less straightforward than in Equation (13), which provides an economic interpretation of the introduction of, or change within, the R&D tax incentive scheme. However, the shift towards more causal interpretations in economic research made direct approaches, and more especially DiD, the most popular way to assess input additionality linked to tax incentives over the most recent period. Consequently, the two streams of literature differ not only in terms of methodological contents but also through the types of

R&D tax incentives evaluated. The design of R&D tax incentives has also evolved over time (see subchapter 6.2.1) and the respective samples composing our study are both biased towards specific designs (e.g. hybrid and incremental mostly evaluated in structural approaches and volume-based among direct approaches). Combining both streams of evaluations allows us to reduce those biases in order to provide a more accurate picture of the effect(s) of different designs.

6.3. Methods

Meta-analysis can be thought of as a collection of statistical analyses used to examine results from individual studies with the general purpose of integrating findings of a given stream of literature (Glass, 1976). Here, we rely on the meta-regression analysis framework introduced by Stanley & Jarrell (2005) and Stanley (2001). Meta-regression analysis is a multivariate approach that aims to assess the existence of a genuine statistical effect characterising the evaluated set of studies and underpinning sources of variations (i.e. the context of implementation, methodology). Doing so provides an averaged effect of the relationship studied in a stream of literature, corrected from a potential publication bias. The meta-analysis framework questions the validity of the empirical results by "filter[ing] out systematic biases, largely due to misspecification and selection, already contained in economics research" (Stanley & Doucouliagos, 2012, p. 13).

6.3.1. Data collection

We collected estimations from publications by crossing two main sources: Google Scholar and IDEAS/RePEc. The selection of publication on Google Scholar relies on the following semantic strategy: alltitle='R&D tax*.[136] The strategy developed to extract publications from IDEAS/RePEc differs slightly by relying on JEL codes[137] standardized across economic fields and countries. In accordance with the JEL code definitions, we combined each query with a keyword search in the whole record ('R&D tax incentive') (for more details, see Appendix 26).[138] The data collection was performed between the 3rd of May 2018 and the 28th of

[136] Various trials showed that specifying 'tax credit' or 'tax incentives' did not help in getting more relevant studies. The variation in vocabularies across communities did not lead to the selection of specific keywords. The advantage of 'tax*' is to cover all potential variations of tax credits, tax reforms, tax incentives.

[137] https://ideas.repec.org/j/.

[138] The drawback associated to our strategy lies in the multiple entries within IDEAS/RePEc due to the use of multiple JEL codes within one publication, and co-authors uploading the paper on multiple depositories, creating several duplicates. However, IDEAS/RePEc helped to complete the initial sample of publications which probably did not refer to R&D taxes in their titles.

September 2018.[139] Only French, Spanish, German, and English publications were used. Finally, we bound the analysis to studies released between 1992-2020 to take into account the increasing use of econometric techniques (General method of moments (GMM) estimations with Arellano- Bond standard errors for structural approaches and DiD in direct approaches) in this field.

6.3.2. Inclusion criteria: structural and direct approaches

We collected the parameter of interest (e.g. β_1 and its respective standard errors in Equation (13) and (14)) linking R&D tax incentives and R&D demand. The data collection has been performed on a subset of literature in both approaches following different criteria: i) the estimations must be at the firm level and for a given country, ii) the estimations are only parametric (exclusion of non-parametric estimations such as the ones focusing on the average treatment effect of the treated (ATT)). Parametric approaches control for other macroeconomic shocks affecting both treatment and control groups and any differences between the two groups of firms that would be constant over time (Bozio et al., 2014). Moreover, the high diversity in the matching procedures before performing an ATT (i.e. propensity score techniques, caliper levels, greedy matching, number of variables coming from different data sources) create substantial sources of variations to account for those in the analysis.[140] Focusing on parametric estimates increases the comparability of the estimates to better tackle the specificities of the tax incentives designs characterising a given country at the studied period. We added another restriction on structural approaches by relying on estimations, which exclusively use the "King-Fullerton" (1984), or "Jorgenson-Hall" (1967) approach to estimate the user cost of R&D. The detailed steps involved in the data collection and inclusion criteria are described in the PRISMA charts (see Appendix 27).

Overall, our samples comprise 21 (structural) and 30 (direct) publications respectively from which we gathered 227 and 507 estimates across the different studies. An overview of the publications used to extract the short-term estimates is presented in Appendix 28 for structural approaches and in Appendix 29 for direct approaches. As the literature focuses mostly on short run effects on R&D, we restrict our analysis to this subset of comparable short-term effects linked to the introduction or change(s) in R&D tax incentive designs. A few studies do not find

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[139] We updated the data collection when new versions of manuscripts got released. We kept Thomson & Skali (2016) initial version considering the high overlap with the published version and the higher number of methods and estimates in the working paper version.

[140] The limited amount of information in some publications makes it also difficult to compute the degrees of freedom.

significant results in the short run because they consider the existence of adjustment costs in claiming tax incentives and adapting the R&D activities (see Labeaga et al., 2014, for an illustration). Those studies tend to rather find significant results in the long run. However, the limited amount of literature that was available did not enable us to conduct the analysis within this time frame.

6.3.3. Meta-Regression Analysis: framework, and modelling choices

The FAT-PET-PEESE (Funnel Asymmetry Test – Precision Effect Test - Precision Effect Estimate with Standard Error) is widely used in economics. This approach decomposes the value of a given estimate in two key parameters. On the one hand, publication bias (FAT) and on the other hand, the averaged true effect through a measure of precision (PET). Publication bias represents a measure for the selectivity of the reported results characterising a subset of studies based on the direction and statistical significance of the results (Rothstein et al., 2006, p. 3). In this modelling context, the publication bias is a function of the standard error. Consequently, the averaged true effect measures the statistical relationship characterising the underpinning subset of literature, net from publication bias. The FAT, which is also known as the Egger's test (M. Egger et al., 1997) is employed to test for the existence of publication bias, e.g. H0: 1,i = 0. This test relies on the assumption that researchers with small sample sizes select the most interesting model(s). It postulates that reported estimates correlate with the size of their standard errors. The net effect measured via the constant provides then the actual averaged (or true) effect associated with the reported estimates characterising the underpinning subset of literature (PET).

$$Estimate_i = \beta_0 + \beta_{1,i} * SE_i + \epsilon_i \quad (15)$$

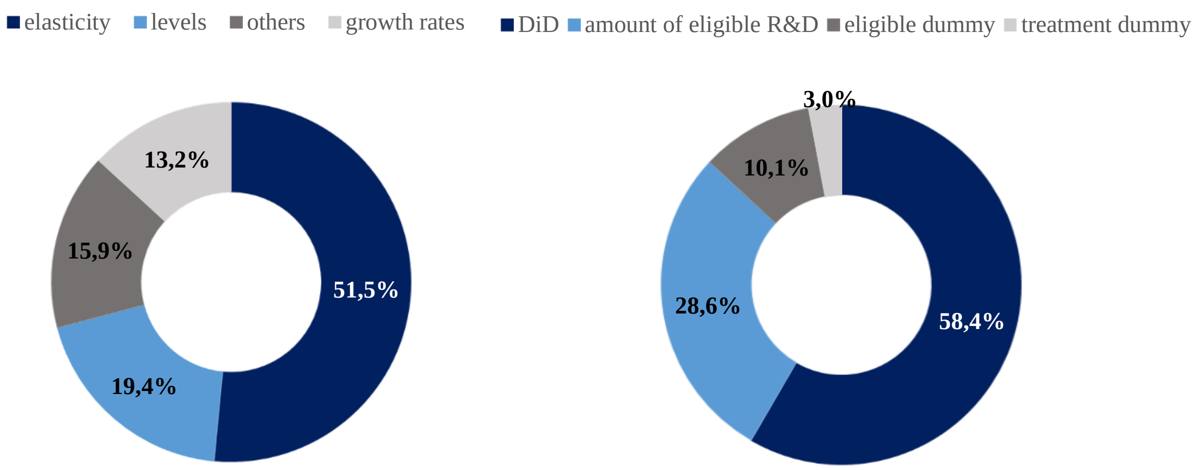
In this context, a given estimate i can be decomposed into a publication selection bias, $\beta_{1,i}$, and β_0 the true statistical effect.

6.3.4. Partial Correlation Coefficient transformation

The diversity of methodologies in both streams of literature (i.e. elasticities with log-log specifications, semi-elasticities with lin-log elasticities, or even growth rates among structural approaches and DiD or treatment dummies among direct approaches) must be tackled to be able to compare the statistical relationships between tax incentives and R&D demand. Figure 19 shows the high diversity characterising the methodologies used to evaluate the impact of R&D tax incentives across the two streams of literature. To be able to compare the statistical effect found across studies, we convert the estimates to a common scale, e.g. Partial Correlation Coefficient (PCC).

Figure 19: Distribution of the methodologies across the two samples

Structural approaches (b) Direct approaches



Source: own illustration and calculation

The PCC transformation takes into account the power of estimations with the degrees of freedom and measures the statistical strength of the relationship between R&D tax incentives and demand for R&D.

$$PCC_i = t_i / \sqrt{t_i^2 + df_i} \qquad (16)$$

where t refers to the t-ratio and df to the degrees of freedom of the relevant estimation. The standard error for the PCC transformation is given by $SE_{PCC} = \sqrt{(1 - PCC^2)/df}$). The PCC is quite robust even if there are slight mismeasurements of the degrees of freedom as these are often not explicitly reported in the primary estimates (Stanley & Doucouliagos, 2012).[141] In line with the previous subchapter, the constant β_0 remains the averaged true effect and β_1 measures the publication bias. Our equation (15) becomes:

$$PCC_i = \beta_0 + \beta_1 * SE_{PCC,i} + \epsilon_i \qquad (17)$$

The drawback of using PCC lies in its interpretation: the estimations depict the strength of the correlation between the two variables studied (e.g. introduction of tax incentives vs. R&D price

[141] A general concern raised in the context of PCC transformation is the problem of asymmetric distribution if the values get close to -1 and +1. However, the underlying datasets face no asymmetric distribution.

and R&D demand). Doucouliagos (2011) conducts a meta-evaluation of the economic literature to determine the distribution of PCC across subfields. In the case of politics and taxes, Doucouliagos (2011) finds on average that a PCC under 0.015 refers to a weak statistical correlation, between 0.015 and 0.037 the effect is medium, between 0.037 and 0.076 is high, and above 0.076 is very high.[142]

6.3.5. Modelling approach

Following the framework developed by Stanley and Doucouliagos (2012) and Stanley (2017), we use a weighted least squares estimation of Equation (17) to account for the heteroscedasticity in the standard-errors composing our samples and the existence of correlation of estimates coming from the same study s (see Equation (18)). With this transformation, the constant (β_0) measures the publication bias while β_1 becomes the averaged true effect measured in a stream of literature. Equation (19) introduces the extended meta-regression analysis. Additional variables are added to test their role in moderating the averaged true effect (Z) and moderating the publication bias (K) in explaining the variations found in the literature. The averaged true effect is now a combination of all Z variables with the precision effect and the publication bias corresponds to the sum of K variables and the constant. The Z and K variables are described in Table 18 and refer to the features of the R&D tax incentives evaluated in a given study.

$$T - stat_{i,s} = \beta_0 * \frac{1}{SE_{PCC,i,s}} + \beta_1 + v_{i,s} \qquad (18)$$

$$T - stat_{i,s} = \beta_0 * \frac{1}{SE_{PCC,i,s}} + \sum_j \delta_j Z_j * \frac{1}{SE_{PCC,i,s}} + \beta_1 + \sum_m \gamma_m K_m + v_{i,s} \qquad (19)$$

We use the inverse of the standard errors as a weight and make a robustness check with the inverse of the variance (PEESE approach).[143] If not indicated otherwise, we use robust and clustered standard errors at the study level to account for correlation among estimates from the same study. This correlation might be the result of research choices in the estimation method, or data sources for example. In our context of analysis, it is even more important to account for dependencies within studies considering the diversity of the tax incentives schemes evaluated.

[142] For more details, see Table 4 in Doucouliagos (2011).

[143] This PEESE approach is supposed to be more efficient in presence of heteroscedasticity (Stanley & Doucouliagos, 2012, p. 78).

For the same reason, we do not add publication fixed effects which would make it impossible to then test the specificities of the tax incentives designs evaluated.[144]

6.3.6. Summary statistics

The results of the data collection at the study level is summarized for both streams of literature in Appendices 28 and 29. Table 18 describes the key variables for the analysis of our study. As expected, estimates from structural approaches tend to find a negative relationship between the price of R&D and its related demand. By contrast, direct approach estimates find a positive relationship between decreasing the R&D costs and the related amount of R&D performed. We observe that on average, structural approaches reveal more statistically significant results than direct approaches. Structural estimates are on average elder than the ones coming from direct approaches and competing explanations can be linked to this difference in terms of statistical significance. The shift towards more causal interpretations in economic evaluations makes recent (and direct) evaluations less significant than structural ones.

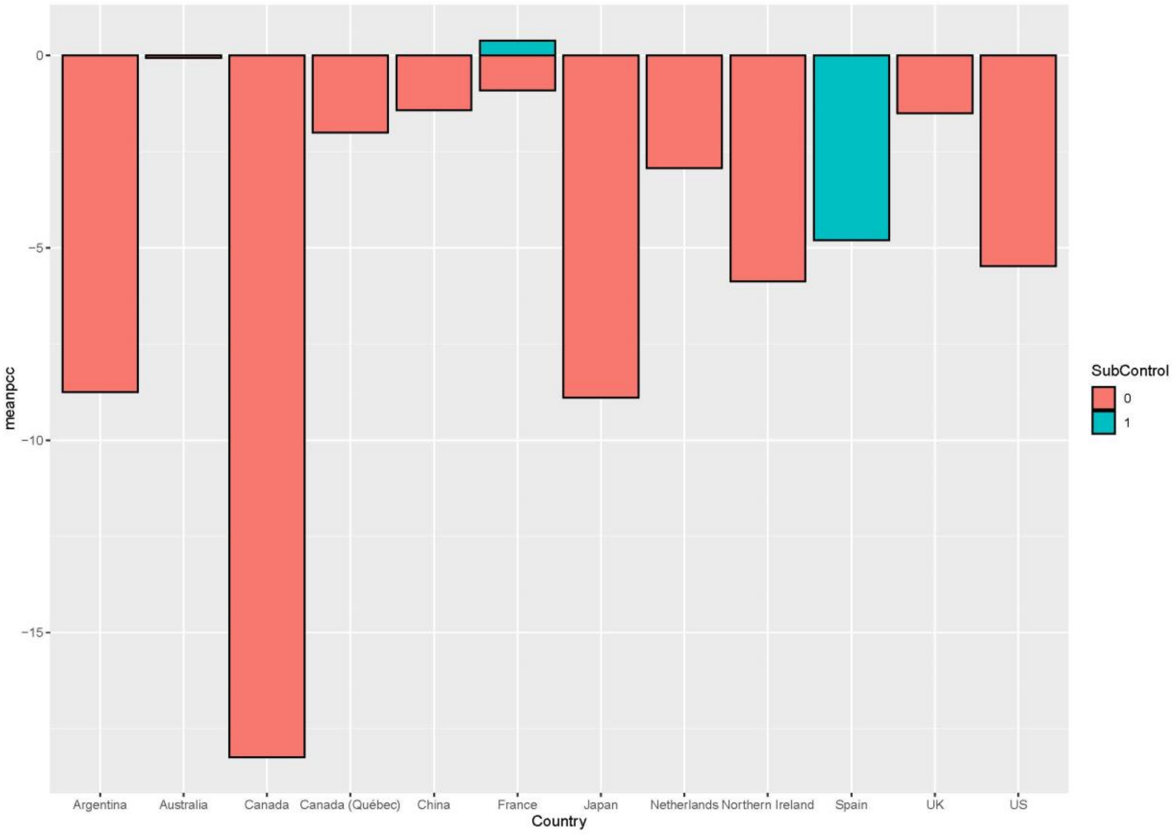
A competing methodological explanation lies in the data source involved. The effect attributed to R&D tax incentives could also be driven by other policies such as R&D subsidies. Few authors could have access to information related to the use of direct R&D subsidies. Figure 20 and Figure 21 provide an overview for the countries composing our two samples and if data is available to add an R&D subsidy control within the analysis. Among structural approaches, only Spanish authors and to some extent French ones were able to control for subsidies. Subsidy controls are more frequent in recent evaluations. However, no specific patterns emerge from both graphs.

Finally, Table 19 suggests an alternative source of variation between the two streams regarding their significance level. As indicated in the second column, the majority of our estimates for structural approaches belongs to countries evaluated in the 1980s and 1990s, associated with hybrid and incremental base evaluations. Direct approaches rather reflect the evaluations of recent schemes (in the 2000s), i.e., volume-based schemes. We take advantage of these specificities across samples to get a more accurate picture of the evolution of tax schemes features and their respective levels of efficiency. Alongside with an over-representation of specific bases, our samples tend to particularly reflect a few countries (US and Spanish estimates in structural approaches, Belgium and British estimates in direct approaches). For this reason, we account for those in various robustness checks. The shift towards volume-based

[144] We could only observe variations from the period or the designs in a given country for France, Spain, and Canada. The set of related estimates was not large enough to exploit within-country variations.

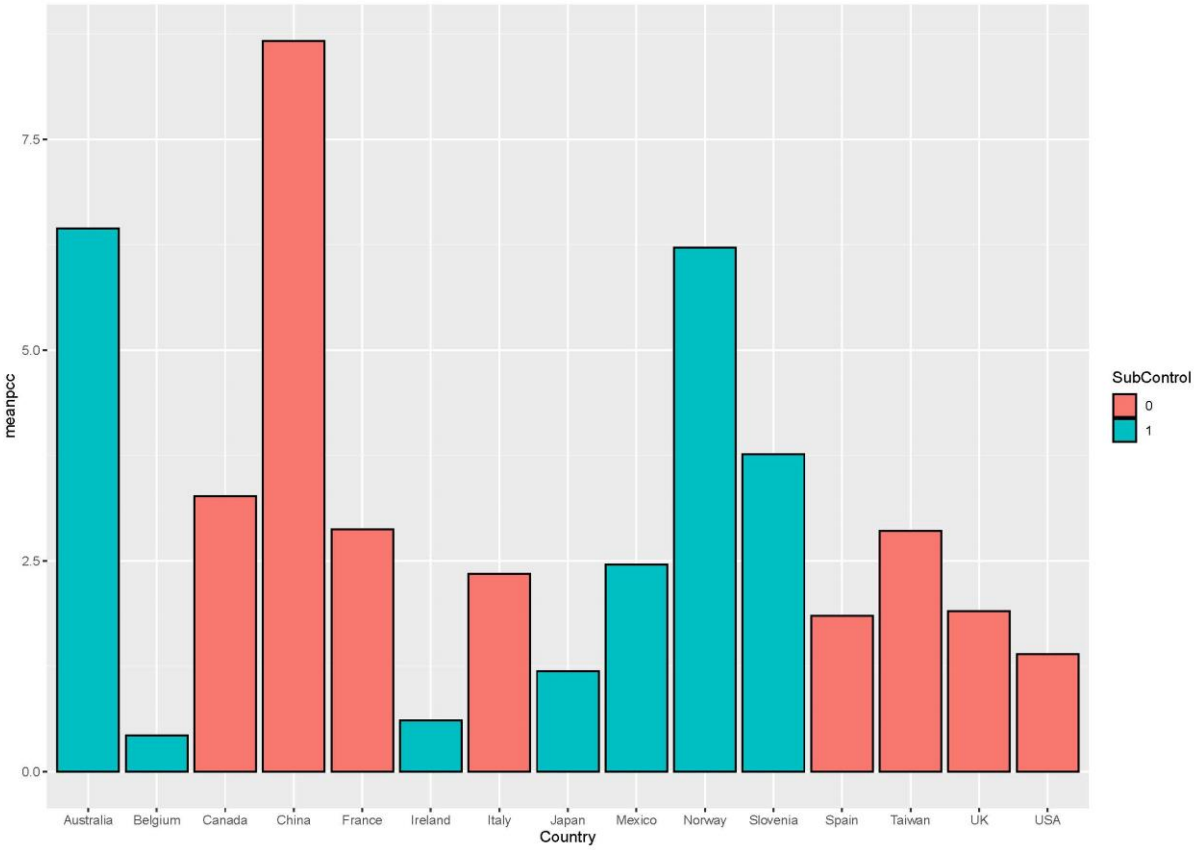
schemes is also underlined in Appendices 30 and 31 that plot the respective values of the PCC coefficients and their level of precision. Appendix 30 suggests that incremental estimates among structural approaches tend to find higher results even if they seem less precise than other evaluated bases. Appendix 31 supports this idea even if the volume-based estimates are over-represented in this sample and exhibit a very high heterogeneity in terms of precision and efficiency.

Figure 20: Distribution of average PCC t-stats across countries and subsidy data (structural sample)



Source: own illustration and calculation

Figure 21: Distribution of average PCC t-stats across countries and subsidy data (direct sample)



Source: own illustration and calculation

Table 18: Variables description and summary statistics

Variable	Definition	Obs.	Mean	St. Dev.	Min	Max
Subsample: Structural approach						
Outcome characteristics						
PCC	Partial correlation coefficient	227	-0.42	0.37	-0.99	0.72
Tstat	Estimated t-statistics of effect size	227	-5.04	6.88	−48.00	6.00
Prec	Inverse of the PCC standard error	227	18.33	19.70	2.26	98.09
Prec_sq	Inverse of the PCC variance	227	722.21	1,599	5.00	9,622
Tax scheme: Z variables[a]						
VolumeSE	1 if volume tax scheme, 0 otherwise	227	5.50	18.37	0.00	98.09
IncrementalSE	1 if incremental tax scheme, 0 otherwise	227	2.53	5.61	0.00	47.00
HybridSE	1 if hybrid tax scheme, 0 otherwise	227	10.302	14.60	0.00	53.00
DeductionSE	1 if enhanced allowance, 0 if tax credit	227	2.19	7.82	0.00	69.00
CarryforwardSE	1 if carryforward exists, 0 otherwise	227	14.75	20.54	0.00	98.09
ApprovalSE	1 if pre-approval required, 0 otherwise	227	3.412	7.923	0.00	37.00
CapSE	1 if tax benefit is limited, 0 otherwise	227	12.38	13.93	0.00	53.00
TargetedSE	1 if SMEs are targeted, 0 otherwise	227	15.29	21.12	0.00	98.09
Methodology: K variables						
IV	1 if IV, 0 otherwise	227	0.25	0.43	0.00	1.00
GMM	1 if GMM, 0 otherwise	227	0.48	0.50	0.00	1.00

Variable	Definition	Obs.	Mean	St. Dev.	Min	Max
Subsample: Direct approach						
Outcome characteristics						
PCC	Partial correlation coefficient	507	0.047	−0.17	−0.17	0.32
TSTAT	Estimated t-statistics of effect size	507	2.113	3.35	−8.03	31.05
Prec	Inverse of the PCC standard error	507	71.09	37.58	6.01	203.53
Prec_sq	Inverse of the PCC variance	507	6,463	7,703	36.09	41,426
Tax scheme: Z variables[a]						
VolumeSE	1 if volume tax scheme, 0 otherwise	507	62.94	40.51	0.00	203.53
DeductionSE	1 if enhanced allowance, 0 if tax credit	507	42.53	41.03	0.00	182.00
CarryforwardSE	1 if carryforward exists, 0 otherwise	507	65.24	42.17	0.00	203.53
ApprovalSE	1 if pre-approval required, 0 otherwise	507	6.35	20.79	0.00	112.00
CapSE	1 if tax benefit is limited, 0 otherwise	507	52.55	39.84	0.00	182.00
TargetedSE	1 if SMEs are targeted, 0 otherwise	507	53.66	46.37	0.00	203.53
BaseSE	1 if a shift towards volume, 0 otherwise	507	8.56	22.55	0.00	155.00
Methodology: K variables						
DiD	1 if DiD, 0 otherwise	507	0.58	0.49	0.00	1.00
Treatment dummy	1 if the authors use a treatment dummy, 0 otherwise	507	0.03	0.17	0.00	1.00
Eligible dummy	1 if the authors use an eligibility dummy, 0 otherwise	507	0.10	0.30	0.00	1.00
Eligible R&D amount	1 if the authors use the eligible R&D amount, 0 otherwise	507	0.29	0.45	0.00	1.00

Notes: [a] Dummy variables are weighted by the inverse of the standard error of the PCC estimate.
Source: own calculation and composition

Table 19: Composition of the samples at the country level (in share of observations)

Country	Period	Base definition			Type	Refund		Restriction		Share of observation
	Post2000	Incremental	Hybrid	Volume	Deduction	Carry-forward	Targeted	Cap	Approval	
Structural										
Argentina	1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	0.08
Australia	0.00	0.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.04
Canada	0.71	0.00	0.21	0.79	0.00	0.71	1.00	0.00	0.00	0.06
China	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.07
France	0.19	0.12	0.75	0.12	0.00	0.88	0.00	0.88	0.00	0.07
Japan	0.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.03
Netherlands	-[a]	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.04
Spain	0.5	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.32
UK	1.0	0.00	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.04
USA	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.27
Direct										
Australia	1.00	0.00	0.25	0.75	0.25	1.00	1.00	0.17	0.00	0.02
Belgium	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.04	0.00	0.24
Canada	1.00	0.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.04
China	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.001
France	1.00	0.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.01
Ireland	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.02
Italy	1.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.01
Japan	1.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	0.00	0.14
Mexico	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	0.01
Norway	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.07
Slovenia	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.001
Spain	1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.01
Taiwan	1.00	0.00	0.67	0.33	0.00	1.00	0.00	0.33	1.00	0.02
UK	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	0.44
USA	0.07	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.08

Notes: [a] Not coded for the period post 2000 dummy due to the overlap of the analysis between the 1990s and 2000s.
Source: own composition

6.4. Results

This chapter presents the main results of the meta-regression analysis among the structural approaches (Table 20) and direct ones (Table 21). The existence of an averaged true effect is then split over time: as mentioned before, R&D tax incentives have increasingly relied on volume related schemes. In parallel, authors have paid stronger attention to endogeneity and selection issues in the evaluations. Both factors are likely to affect the magnitude and the level of statistical significance found in the literature over time. We account for both by conducting an extended meta-analysis regression on the "best practices" in the two streams of literature (i.e. Instrumental Variable (IV) and GMM estimations among the structural approaches (Table 22) and the DiD estimates (including RDD) among the direct approaches in Table 23). Doing so aims at testing each policy features behind the evaluations by relying on more reliable and homogeneous estimates.

6.4.1. Structural approaches: overall effect over time

Table 20 presents the main results testing the existence of an averaged true effect of R&D tax incentives on R&D expenditures among structural approaches. We find a negative and significant effect of the averaged true effect across all different specifications. In other words, tax incentives associated with a reduction in the price of R&D lead to a significant statistical increase in R&D spending. However, the FATPET estimate (column 1) indicates a strong publication bias (e.g. magnitude over 2, see Ugur et al., 2016), suggesting that on average authors tend to overestimate the effect of tax R&D incentives on R&D expenditures in the short-run. Subtracting the estimated publication bias (-0.295) from the reported effect size of R&D tax incentives (-0.142) converts the average true effect even to a positive value (+0.153).[145] In contrast, the PEESE estimate (column 2) shows no publication bias and a significantly stronger effect of R&D tax incentives than the FATPET estimate. These two results suggest a high heterogeneity in terms of methods and/or policies that require an extended analysis to measure those sources of biases.

We start testing potential sources of heterogeneity through the over-representation of specific countries (columns 3 to 5 looking at the US and Spanish estimates), the observation period (columns 4 and 5) as well as the methodological biases (columns 6 and 7). Column 3 introduces a US dummy to test the role of this specific environment as a context of evaluation. We show

[145] The average magnitude of publication selection bias is a linear combination of the constant term and each estimated effect of moderating variables (i.e. unweighted dummy) weighted by their mean value (x), multiplied by the average standard error: $(\beta_0 + \beta_k * x) * SE$.

that on average studies evaluating the US R&D tax incentives tend to find higher results than evaluations from other countries. In contrast to the general FATPET, an effect of R&D tax incentives on R&D spending (-0.06) remains even after correcting the average true effect for the US publication bias (-0.11). We replicate the same approach in columns 4-5 with a Spanish dummy since we observe estimates across two periods.[146] As the design of R&D tax incentives has evolved towards volume-based schemes in recent years (see Table 19), we delineate our sample between early estimates covering the 1980s to 1990s and estimates from the 2000s.[147] Although we find a significant negative averaged true effect in both periods, its magnitude decreases over the most recent period and is closed to our main FATPET estimate (column 1). The magnitude of the average R&D tax incentives effect in the 1980s and 1990s is almost 3 times higher than in the more recent period, which corresponds to the adoption of volume-based schemes. We also document in column 5 a lower effect of tax incentives for Spain over the most recent period[148]: several empirical studies support our finding by putting to the front the unawareness, administrative costs due to the complexity of the application process, and a high risk of an inspection by tax authorities as the main barriers for using R&D tax incentives (Busom et al., 2014). Consequently, firms have fewer incentives to bear the cost of applying for tax credits than to apply to R&D subsidies (Martínez-Azúa & Ros, 2009).[149] Moreover, the capacity to control for R&D subsidies in Spanish evaluations might also explain why the effect of tax incentives is smaller than in other countries.

As mentioned in the literature background, the shift towards volume-based schemes over the most recent period went with an increasing use of methods to better tackle endogeneity and selection. To disentangle between both, we start by testing if the observed decline in the average true effect over time coincides with a shift toward more rigorous analysis. Thus, we focus on estimates relying on IV approaches to proxy the effect of the user costs (e.g. lagged values of the user cost, or the (synthetic) tax component of the user cost) and GMM estimates in column 6. Surprisingly, we document a higher magnitude in the publication bias and average true

[146] Our set of US estimates focuses exclusively on the 1980s and 1990s and does not allow us to replicate the same models as in columns 4-5.

[147] We drop 12 observations relating to three papers (i.e. Baghana and Mohnen (2009); Lokshin & Mohnen (2007, 2012)) as they cannot be assigned to either the late 1990s or 2000s. This affects all Dutch and 29% of Canadian estimates in the sample split between the two periods.

[148] After correcting for the estimated publication bias of Spanish estimates (+0,108), we find that the effect of R&D tax incentives (-0.262) is almost halved compared to the earlier period.

[149] Labeaga et al. (2021) report that applicant firms are motivated by reducing the corporate tax burden rather than by substantially increasing R&D spending. Still, they also argue that once companies have borne the cost of learning how to apply, they persistently claim R&D tax credits. This learning effect could explain the higher effectiveness of the long-run estimates found by Labeaga et al. (2014).

effect.[150] While the higher averaged true effect can be explained by specific underpinning country estimates (US ones), we also observe a strong publication bias among the most reliable estimates. We further split each subsample in columns 7 and 8, taking into account a potential bias of the most recent Spanish estimates. In line with our literature review, column 7 shows that GMM estimates find on average less significant results than other methodologies. We observe a much higher average true effect of R&D tax incentives in column 8, which is heavily driven by the amount of US estimates and consistent with our results estimated in columns 3 and 4.[151] The differences of effectiveness across the Spanish and US estimates tend to exacerbate the publication bias coming from Spain as the context of evaluation. We extend this assessment with the set of estimates coming from direct approaches, which corresponds to more recent periods to dig into the policy design(s) that could explain this lower effect.

6.4.2. Direct approaches: evolution of methodologies versus policy design

Table 20: Meta-regression analysis: structural approaches

	Dependent variable: t-stat (PCC transformation)							
	FATPET	**PEESE**	**US**	**Pre2000**	**Post2000**	**Best practice**	**GMM**	**IV**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Prec	−0.142*** (0.066)		-0.170*** (0.064)	-0.441** (0.179)	-0.154** (0.070)	-0.177** (0.054)	-0.127* (0.075)	-0.362*** (0.011)
Prec_sq		-0.227*** (0.044)						
US			-3.371*** (1.270)					
Spain				0.590 (2.237)	3.535** (1.396)			
Spainpost							6.982** (2.773)	17.671*** (0.794)
Constant	−2.433** (0.957)	16.238 (34.882)	-1.013 (1.211)	-0.729 (1.527)	-1.754 (1.964)	-2.360 (0.845)	-2.781** (1.145)	-2.906*** (0.805)
Obs.	227	227	227	114	101	164	108	56
R2	0.167	0.540	0.208	0.268	0.308	0.237	0.133	0.859
Adj. R2	0.163	0.538	0.200	0.255	0.294	0.232	0.116	0.854

Notes: We report standard errors clustered by study in parentheses. ***, **, * denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.
Source: own calculation and composition

We start the analysis of direct approaches by looking at the existence of an averaged true effect among the R&D tax incentives evaluations in Table 21. Estimations in Table 21 aim at assessing to what extent the results found in Table 20 for structural approaches hold among more

[150] The publication bias in column 1 is 0.29 and overcompensates the true effect, suggesting an absence of a statistical effect of R&D tax incentives. Column 6 exhibits a publication bias of 0.30 which again overcompensates the average true effect relating to tax incentives and R&D demand. Studies controlling for endogeneity bias tend to report lower estimates and thus, publication bias arises as researchers need larger estimates to offset large standard errors.

[151] This finding is consistent with the graphical analysis provided in Appendix 30.

recent estimates. As stressed earlier, the evolution of the policy design towards volume-based schemes makes direct approaches an interesting lens to complete the assessment done with elder estimates. The FATPET estimation (column 1) shows that the studies using direct approaches find on average a positive and significant effect of R&D tax incentives on R&D spending. The PEESE estimation (column 2) supports the previous finding even if the effect seems to be less statistically significant. The variance weight seems to increase, suggesting a high heterogeneity across evaluations. We replicate what we did before by looking at the existence of a potential bias coming from an over-representation of a country in the sample before looking at additional sources of policies in explaining the heterogeneity of the results found in the literature.

We start by testing if evaluations looking at the UK as a context of analysis are responsible for creating a bias considering the large amount of UK estimates in the sample.[152] We cannot show a specific country effect in this sample even if we see a decrease in the statistical significance of the R&D tax incentives effectiveness. Like in Table 20, we test if more recent evaluations find lower results than in the earliest ones. Columns 4 to 8 focus exclusively on estimates from the 2000s. Column 4 shows a similar averaged true effect as the one estimated in column 3, suggesting that column 3 catches the effect of more recent estimates which exhibit a lower averaged true effect than in the overall sample (column 1). We test in column 5 whether this lower averaged true effect is mostly the result of a methodological shift towards more accurate methods to evaluate R&D tax incentives. We do find that evaluations relying on treatment, or eligible, dummies tend to overestimate the effect of R&D tax incentives on R&D spending than studies using the amount of eligible R&D. We do not see any statistical difference with studies using DiD settings which may also come from other policy settings.

Columns 6 to 8 test a competing explanation, linking the transition towards volume-based schemes with the lower effect documented in columns 4 to 5. In line with our previous results, we find that studies evaluating volume-based schemes estimate a lower effect than studies evaluating incremental and hybrid schemes. Column 6 suggests that the averaged true effect of volume-based schemes is around 0.03 while the averaged true effect of hybrid and incremental is on average around 0.1. We further split the subset of volume-based estimates associated with the 2000s into two subsamples: evaluations associated to shift towards the volume-based (column 7) and the introduction of volume-based estimates (column 8). Splitting among the most recent estimates substantially reduces the number of estimates in each sample. We

[152] We further remove the UK unpublished estimates in column 3 to increase their comparability.

introduce a country dummy to account for the large amount of Belgium estimates (50%) in this column. Despite a lower number of observations, column 8 still shows a weak but significant effect of the introduction of volume-based schemes. On the contrary, column 7 suggests that on average estimations related to a shift within an existing tax incentive scheme do not find significant results on average in stimulating R&D expenditures. This is consistent with the idea that uncertainty reduces the effectiveness of R&D tax incentives (see subchapter 6.2.1.3); numerous changes over a short period of time create uncertainty and firms must adapt and learn about this changing institutional landscape to benefit from R&D tax incentives (OECD, 2014). Short-run estimates are therefore less likely to find statistically significant results in this context. As suggested by the Belgium dummy, results are however very different across countries despite sharing the same base definition. The next section looks in-depth at the role played by additional design features in explaining the heterogeneity of the results found in the literature among the most comparable estimates.

6.5. Robustness checks

This set of estimations relies on the best practices in both streams of literature evaluating the impact of R&D tax incentives on R&D spending. The structural subsample consists of IV

Table 21: Meta-regression analysis: direct approaches

	Dependent variable: t-stat (PCC transformation)							
	FATPET	**PEESE**	**UK**	**Post2000**	**Method**	**Volume**	**Shift to volume**	**Intro volume**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Prec	0.023** (0.011)		0.028* (0.015)	0.034* (0.020)	0.034* (0.020)	0.103*** (0.026)	0.027 (0.019)	0.088* (0.046)
Prec_sq		0.025*** (0.009)						
UK			0.212 (0.617)					
Treatment Dummy					4.054*** (1.533)			
DiD					1.080 (0.667)			
VolumeSE						-0.075*** (0.028)		
BaseSE							-0.015 (0.010)	
Belgium								-4.867*** (1.141)
Constant	0.471 (0.598)	23.488 (39.455)	0.316 (0.764)	0.088 (1.005)	-0.793 (1.243)	0.250 (0.711)	0.725 (0.733)	-0.403 (2.573)
Obs.	507	507	353	315	315	315	168	138
R2	0.067	0.208	0.085	0.111	0.201	0.218	0.174	0.385
Adj. R2	0.065	0.207	0.079	0.108	0.193	0.213	0.164	0.376

Notes: We report standard errors clustered by study in parentheses. ***, **, * denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.
Source: own calculation and composition

estimations and GMM. The direct subsample is composed of RDD and DiD estimations. Both samples aim at tackling the endogeneity and selection effects related to the decision in claiming R&D tax incentives. Restricting the samples to those methodological choices reduces the sources of variations to the evolution of the policy designs. However, doing so restricts the number of countries in the robustness checks. The direct estimates provide a more consistent frame by looking mostly at volume-based evaluations, limiting the variations from the base definition. On the contrary, structural approaches combine variations in the base schemes that make it difficult to isolate the marginal effect of additional features (e.g. refund rules, cap, and approval). The results across Table 22 and Table 23 confirm the role of the policy designs in explaining the differences observed over time and across countries.

6.5.1. Structural approaches: IV and GMM estimates

Table 22 presents a set of models tested on a subset of structural estimates that represent the "best practices" in the field (i.e. IV approaches and GMM estimations to tackle endogeneity and selection issues). While Table 20 suggests differences in the subsample of GMM estimates, column 1 in Table 22 shows only a weak statistical effect. Consistent with our overview of the field, estimations with GMM tend to find lower estimates than other modelling approaches. We find that on average R&D tax incentives have an impact on R&D demand even if among those best approaches, we document a strong and significant publication bias.[153] Controlling for policy specificities beyond the set of Spanish estimates from the 2000s makes the publication bias insignificant (see columns 2 to 10). This finding supports our framework explaining the heterogeneity of the results characterising this stream of literature by the evolution of the R&D policy designs.[154] We further restrict our estimations to the US published estimates in columns 2 to 10 to reduce their weight in the sample based on our findings in Table 20.

We do not control for our Spanish outliers due to a too high correlation with the hybrid variable (see Appendix 32). We remove those in column 5 that translates into a higher averaged true effect, consistent with their positive values in columns 1 to 4. Overall, we find an average true effect related to incremental and volume-based estimations in models 4 and 5 but no enhancing, or detrimental, effect related to hybrid schemes. Column 6 confirms this finding by exhibiting an averaged true effect reflecting the result estimated in column 3 for incremental and a net effect of volume-based schemes corresponding to the averaged true effect estimated in columns

[153] Even after controlling for the estimated publication bias of 0.17 in column 1, a negative true effect remains.

[154] The importance of policy variations in explaining the contrasting effects depicted in the literature is also supported by the absence of significance of the GMM dummies in columns 2 and 3.

Table 22: Extended MRA: tax incentives designs (structural approaches)

	Dependent variable: t-stat (PCC transformation)									
	Biases (1)	**Type (2)**	**Incremental (3)**	**Hybrid (4)**	**Hybrid w/o Spain (5)**	**Volume (6)**	**Targeted (7)**	**Carry forward (8)**	**Approval (9)**	**Cap (10)**
Prec	-0.234*** (0.031)	-0.237*** (0.047)	-0.224*** (0.032)	-0.199*** (0.024)	-0.237*** (0.024)	-0445*** (0.101)	-0.716*** (0.259)	-0.353*** (0.088)	-0.247*** (0.030)	-0.246*** (0.026)
DeductionSE		0.235*** (0.059)								
IncrementalSE			-0.189*** (0.066)							
HybridSE				0.094 (0.124)	-0.146 (0.117)					
VolumeSE						0.214** (0.089)				
TargetedSE							0.445* (0.245)			
Carry-forwardSE								0.112 (0.077)		
ApprovalSE									0.075 (0.081)	
CapSE										-0.269*** (0.095)
GMM	3.389* (1.758)	3.241 (3.616)	3.629 (3.798)	2.469 (4.037)						
Spainpost						17.806*** (3.618)				
Spain							-4.411*** (1.193)	-3.462*** (1.173)		
US									-2.680 (1.711)	-3.888*** (1.257)
Constant	4.369*** (1.326)	4.734 (3.554)	4.347 (3.591)	4.359 (3.286)	0.355 (1.115)	0.572 (1.142)	1.616 (1.349)	0.203 (1.317)	1.107 (0.906)	1.861 (1.288)
Obs.	164	127	127	127	115	127	115	115	115	115
R2	0.403	0.442	0.428	0.298	0.392	0.441	0.410	0.401	0.385	0.473
Adj. R2	0.392	0.424	0.409	0.298	0.382	0.427	0.394	0.385	0.368	0.459

Notes: We report standard errors clustered by study in parentheses. ***, **, * denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.
Source: own calculation and composition

3 and 5. In line with our framework, the shift towards volume-related schemes has come with a decreasing effect of R&D tax incentives on R&D spending.

We investigate the role of secondary features linked to those scheme changes in columns 7 to 10. Due to the correlation with the Spanish outliers with each specific policy feature, we drop those and introduce another Spanish dummy in columns 7 and 8 and a US one in columns 9 and 10 considering their respective importance of those subsamples. As a consequence, the magnitude of the averaged true effect in columns 6 and 7 increases by rather reflecting the US estimates as a reference category. We do not find a statistical effect linked to targeted schemes and carry forward rules most likely due to the variety of base definitions underpinning our subsample of structural estimates. The strong effect of incremental schemes that on average does not come with targeted refund rules for SMEs is probably responsible for blurring potential statistical effects of targeted or carry-forward rules. Columns 9 and 10 substitute the Spain dummy for a US one due to multicollinearity and is responsible for decreasing the averaged true effect. On average, we find that approval does not increase the effectiveness of the evaluated scheme but introducing a cap has on average an enhancing effect on R&D tax incentives effectiveness. To complete this assessment, we rely on our set of direct approach estimates that are more homogeneous (e.g. mostly volume-based).

6.5.2. Direct approaches: DiD estimates

Comparing more similar estimates in Table 23 changes the results we initially obtained in Table 21: column 1 does not show any weak statistical significance characterising the effect of R&D tax incentives on R&D spending while we document a positive and significant publication bias. Using the estimated constant, we find an average estimated publication bias for the direct approach sample of +0.03. This last result suggests that even with appropriate methods, authors tend to overestimate the results attributed to R&D tax incentives. The absence of significance of the averaged true effect is also likely to reflect cancelling effects coming from very distinct designs. We investigate the role of the policy features in columns 2 to 7.[155] Column 2 tests whether enhanced deductions versus tax credits are the most efficient way to design R&D tax incentives. We do not find a significant difference between both systems. Column 3 looks at whether the base definition represents a source of heterogeneity among the estimates composing our sample of DiD studies. On average, we find that studies evaluating volume-based schemes tend to find significant and positive results. This result contradicts what we find

[155] For the respective correlation matrix, see Appendix 33.

Table 23: Extended MRA: tax incentives designs (DiD approaches)

	Dependent variable: t-stat (PCC transformation)						
	FATPET	**Type**	**Volume**	**Targeted**	**Carry forward**	**Approval**	**Cap**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Prec	0.015 (0.010)	0.014 (0.009)	-0.007 (0.006)	-0.005 (0.008)	0.069*** (0.014)	0.015** (0.006)	0.018** (0.008)
DeductionSE		-0.007 (0.014)					
VolumeSE			0.023*** (0.009)				
TargetedSE				0.021** (0.009)			
CarryforwardSE					-0.052*** (0.009)		
ApprovalSE						0.056*** (0.004)	
CapSE							0.029 (0.024)
Constant	1.717*** (0.564)	1.998** (0.807)	1.678*** (0.642)	1.735*** (0.631)	0.720 (0.752)	0.900 (0.645)	0.074 (1.425)
Obs.	142	142	142	142	142	142	142
R2	0.052	0.057	0.075	0.073	0.292	0.327	0.147
Adj. R2	0.046	0.043	0.062	0.059	0.282	0.317	0.135

Notes: We report standard errors clustered by study in parentheses. ***, **, * denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.
Source: own calculation and composition

in Table 4 but is explained by the next column: only evaluations of volume-based and targeted towards SMEs schemes tend to find a positive and significant effect on R&D expenditures (see column 4). The similarity of columns 3 and 4 results from the lack of variations in this subsample (mostly volume-based and targeted).

We further disentangle the underpinning targeting mechanism by looking at the refund rule in column 5: studies evaluating schemes with carry-forward rules tend to find lower effects than those with immediate refund rules for SMEs. The net effect of an immediate refund rule for SMEs is almost three times higher than in the case of a classic carry-forward. We finally test to what extent increasing the predictability of the revenue claimed is also a source of variations across studies. Having a pre-approval system enhances the effect of R&D tax incentives on R&D spending while we cannot document a specific effect linked to introducing a cap.

6.6. Conclusion

Our study reviews the evolution of the R&D tax incentives over time and aims at assessing to what extent the evolution of the policy designs leads to the ambiguous results found in the literature. Our meta-analysis regressions rely on the two streams of literature (i.e. structural and direct approaches) evaluating empirically the impact of R&D tax incentives on R&D spending in the short run. We document with both streams of literature a more nuanced effect of R&D

tax incentives on R&D spending than what is traditionally assumed in the innovation literature. We stress the existence of publication bias and more importantly, the changing average effectiveness of R&D tax incentives over time (before the 2000s and after the 2000s). Controlling for methodological variations, we show that the heterogeneity observed in the literature and over time reflects the shift towards a volume-based definition. We find a higher effect coming from an incremental base that is mostly explained by the stronger incentive to continuously increase R&D expenditures. We observe a positive effect of volume-based schemes which is moderated by several factors: estimations related to a targeted SMEs framework with a specific refund rate and rule (immediate) seem to drive the positive results found in the literature. Those features moderate uncertainty which is particularly important for SMEs, more financially constraint than large firms in their decision to conduct R&D. A specific attention to SMEs seems to be an important driver in explaining their comparatively stronger response to tax incentives found in the literature (for example, see A. Agrawal et al., 2020; Cappelen et al., 2010; Guceri & Liu, 2019).

The complexity and stability of the scheme seem to be another source of variations explaining the heterogeneity of the results over the most recent period. The underpinning complexity of the hybrid case makes it less effective than the incremental and volume definitions. This result is in line with numerous robustness checks in which we test to what extent numerous changes within the base definition are responsible for decreasing the average effect of R&D tax incentives. Overall, the results across our samples highlight the importance of creating a clear and stable institutional framework to claim R&D tax incentives to enhance its effectiveness. In this regard, introducing a cap or a pre-approval process does not decrease the average effectiveness of R&D tax incentives, and on the contrary, tend to enhance the averaged effectiveness of R&D tax incentives. Hence, both can be used by governments to better plan the revenue foregone associated with R&D tax incentives.

Our study is not without limitations regarding the scope of our results linked to a limited amount of countries in each sample. This issue is all the stronger regarding the type of tax incentives and in Table 22 where the different base definitions combined with a limited amount of variations in the other features reduce our capacity to test those. Our results regarding the additional features beyond the base definition should therefore be taken with caution. Ongoing efforts at the OECD may provide an interesting source of estimations to perform further meta-analyses on the topic by enlarging the number of countries and schemes (Appelt et al., 2020). By the same token, further research should look at the role of R&D subsidies combined with R&D tax incentives. As shown in our descriptive statistics, few authors are able to combine datasets to address this issue. Finally, reviewing the dedicated literature on R&D tax incentives shows that fewer evaluations look at the long-term effect on R&D additionality (Labeaga et al., 2014; as an illustration, see Mulkay & Mairesse, 2013). This bulk of studies stresses the importance of adjustment costs in learning how to claim, and the persistence of using this indirect instrument after bearing the initial costs of claiming (Labeaga et al., 2021). Further research may also examine more systematically the impact of R&D tax incentives on output additionality. Evidence remains scant (Czarnitzki et al., 2011; Dechezleprêtre et al., 2020) and intensifying the efforts would provide an interesting lens to discuss R&D relabelling issues across schemes.

7. Summary

(1) This dissertation addresses three central questions. First, how have international tax systems for corporate investment and investment in labour, innovation and digitalisation evolved over the last decade and what are the important drivers? Second, to what extent is tax competition and location attractiveness driven by R&D tax incentives and how is it impacted by stronger substance requirements? Third, how does the evolution of R&D tax incentives and their design features impact their overall effectiveness in incentivizing R&D activity?

(2) Two studies address the first question of this dissertation. The international tax environment for corporate investment in traditional and digital business models varies widely across the countries considered, leading to large differences in effective tax burdens. Nevertheless, international tax competition is intensifying as statutory and effective corporate tax rates for traditional business models are declining, albeit at a slower pace over the last decade. In contrast, tax competition for investments in digital business models has increased due to targeted incentives for digital assets (in the form of increased or accelerated depreciation), which is further enhanced by a higher share of current expenses characterising digital businesses. Furthermore, the focus on the development of new software solutions and other intangible assets often results in the applicability of R&D tax incentives, which have a strong tax-reducing effect on the effective tax burden. These developments suggest that tax competition is moving away from general reductions in corporate tax rates towards more targeted measures to encourage specific types of investments. However, the decision on a minimum corporate tax rate can set a new lower bound in the corporate race to the bottom.

(3) The increasing international demand for highly qualified workers due to growing investments in digitalisation and the limited labour supply, increase international competition. The large spread in effective labour tax burden on the studied countries indicates a high risk of tax distortions, in particular as the empirical literature indicates that it is increasingly difficult to pass on the tax burden to highly qualified employees. A reduction in the tax wedges, which are comparatively high in most countries analysed and particularly among Central and Western EU countries, is required to remain or improve the location attractiveness for investments in the knowledge-based, digital economy. In addition, the decision on a corporate minimum tax and the fast-approaching digitalisation of firms might shift the focus of tax competition from corporate tax burdens to effective tax levels of highly skilled employees.

(4) Due to international scrutiny on preferential tax regimes, countries rely increasingly on R&D tax incentives to attract foreign R&D activity and to stimulate domestic innovation activity. These measures reduce the effective tax burden significantly and could also lead to negative effective tax burdens, which shows that government are effectively subsidizing these types of investment. In particular, the combination of several tax incentives can result in excessive reductions in the effective tax burden. Thus, countries not following this trend lag behind in their locational tax attractiveness. In accordance with the policy intention to prevent artificial profit shifting, the application of stronger substance requirements, i.e., the Modified Nexus Approach, prevents excessive reductions in effective tax burdens for IP box regimes which could be used to shield other types of income from taxation.

(5) Addressing the third question of this dissertation provide valuable insights into policymaker concerns about the optimal design of R&D tax incentives. Analysing the evolution of tax incentives and their impact on firm's R&D spending over time with a meta regression of existing literature indicates a more nuanced effect of R&D tax incentives. This, especially reflects a shift to volume-based incentives in more recent periods. Disentangling different design features reveals that among the current prevailing volume-based tax incentives, targeted mechanisms towards SMEs are the crucial characteristic to incentives R&D spending. Further, introducing caps or a pre-approval mechanism do not seem to be detrimental for the effectiveness of R&D tax incentives. This finding implies that sources of uncertainty regarding the timespan, the amount of the financial returns from tax claims but also the main criteria to apply are likely to decrease their effectiveness in the short run.

(6) In a nutshell, the self-contained sections provide answers to the three central questions that this dissertation raises. First, corporate tax competition is still a pressing issue and this even more in a digitalised economy. However, current developments in corporate taxation and the digital transformation might shift the focus of tax competition from the corporate to the effective tax levels of highly skilled employees. Second, despite stronger substance requirements R&D tax incentives are a major driver of tax competition nowadays, and they will play an even more critical role with an increasing transformation in a knowledge-based, digital economy. Third, R&D tax incentives are an effective tool to stimulate R&D expenditures. However, their effect is moderated by the underpinning features. Disentangling different design features reveals the importance of creating a clear and stable institutional framework.

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APPENDIX

A. Appendix to Chapter 2

Appendix 1: Company taxation: Statutory tax rates and effective average tax rates at the corporate level, 2009 and 2019 (in %)

Corporation	(1) Statutory tax rates	(2)	(3) Combined profit tax rates	(4)	(5) Domestic EATR	(6)
	2009	2019	2009	2019	2009	2019
EU member states						
Austria	25.0	25.0	25.0	25.0	22.7	23.1
Belgium	33.0	29.0	34.0	29.6	24.7	25.0
Czech Republic	20.0	19.0	20.0	19.0	17.5	16.7
Denmark	25.0	22.0	25.0	22.0	22.6	19.8
Finland	26.0	20.0	26.0	20.0	23.6	19.6
France	33.3	33.3	34.4	35.4	34.7	33.5
Germany	15.0	15.0	30.9	31.6	28.0	28.9
Hungary	16.0	9.0	21.4	11.1	19.5	11.1
Ireland	12.5	12.5	12.5	12.5	14.4	14.1
Italy	27.5	24.0	31.3	27.7	27.5	23.8
Luxembourg	21.0	17.0	28.6	24.9	25.0	21.8
Netherlands	25.5	25.0	25.5	25.0	22.2	22.5
Poland	19.0	19.0	19.0	19.0	17.5	16.0
Slovakia	19.0	21.0	19.0	21.0	16.8	18.7
Slovenia	21.0	19.0	21.0	19.0	19.1	17.3
Spain	30.0	25.0	35.7	30.6	32.8	29.0
Sweden	26.3	21.4	25.7	21.4	23.2	19.4
United Kingdom	28.0	19.0	28.0	19.0	28.3	20.2
Third countries						
Japan	30.0	23.2	40.7	31.3	41.7	34.1
Norway	28.0	22.0	28.0	22.0	26.5	20.8
Switzerland	21.2	21.1	21.2	21.1	18.7	18.6
United States	35.0	21.0	38.8	28.0	37.4	27.5
Brazil	24.0	24.0	34.0	34.0	25.9	25.0
China	25.0	25.0	25.0	25.0	23.9	23.9
India	30.0	30.0	45.2	46.3	39.9	40.8
Russia	20.0	20.0	20.0	20.0	20.7	19.1
Mean overall	24.5	21.6	27.5	24.7	25.2	22.7
Standard deviation	5.7	5.0	7.5	7.3	7.0	6.5
Mean EU member states	23.5	20.8	25.7	23.0	23.3	21.1
Standard deviation	5.8	5.6	6.0	6.2	5.3	5.4
Mean Third countries	26.7	23.3	31.6	28.5	29.3	26.2
Standard deviation	4.7	3.0	8.8	8.2	8.4	7.2

Source: own composition based on Spengel et al. (2021), own calculation for transition economies.

Appendix 2: Effective average tax rates on corporate investment, 2009-2019 (in %)

	2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
AT Austria											
EATR	22.7	23.0	23.0	23.0	23.1	23.1	23.0	22.7	23.1	0.4	0.4
Δ to previous year		0.3	0.0	0.0	0.1	0.0					
BE Belgium											
EATR	24.7	25.9	26.5	27.8	29.3	25.0	26.5	24.7	29.3	4.6	0.3
Δ to previous year		1.2	0.7	1.3	1.5	-4.4					
CZ Czech Republic											
EATR	17.5	16.7	16.7	16.7	16.7	16.7	16.8	16.7	17.5	0.8	-0.9
Δ to previous year		-0.9	0.0	0.0	0.0	0.0					
DK Denmark											
EATR	22.6	22.6	22.0	21.3	20.1	19.8	21.4	19.8	22.6	2.8	-2.8
Δ to previous year		0.0	-0.7	-0.6	-1.3	-0.2					
FI Finland											
EATR	23.6	24.7	22.7	18.9	19.5	19.6	21.5	18.9	24.7	5.8	-4.0
Δ to previous year		1.0	-2.0	-3.7	0.6	0.1					
FR France											
EATR	34.7	32.8	34.7	38.3	33.4	33.5	34.6	32.8	38.3	5.5	-1.2
Δ to previous year		-1.8	1.8	3.6	-4.9	0.1					
DE Germany											
EATR	28.0	28.2	28.2	28.2	28.8	28.9	28.4	28.0	28.9	0.9	0.9
Δ to previous year		0.2	0.0	0.0	0.6	0.1					
HU Hungary											
EATR	19.5	19.3	19.3	19.3	11.1	11.1	16.6	11.1	19.5	8.4	-8.4
Δ to previous year		-0.2	0.0	0.0	-8.2	0.0					
IE Ireland											
EATR	14.4	14.4	14.4	14.1	14.1	14.1	14.3	14.1	14.4	0.3	-0.3
Δ to previous year		0.0	0.0	-0.3	0.0	0.0					

Appendix 2: Effective average tax rates on corporate investment, 2009-2019 (in %) (continued)

		2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
IT	**Italy**											
EATR		27.5	24.9	25.1	23.8	23.7	23.8	24.8	23.7	27.5	3.8	-3.7
Δ to previous year			-2.6	0.2	-1.3	-0.1	0.2					
LU	**Luxembourg**											
EATR		25.0	25.0	25.5	25.5	23.7	21.8	24.4	21.8	25.5	3.7	-3.2
Δ to previous year			0.0	0.6	0.0	-1.8	-1.8					
NL	**Netherlands**											
EATR		22.2	21.8	21.7	22.5	22.5	22.5	22.2	21.7	22.5	0.8	0.3
Δ to previous year			-0.4	-0.1	0.9	0.0	0.0					
PL	**Poland**											
EATR		17.5	17.5	17.5	17.5	17.5	16.0	17.2	16.0	17.5	1.5	-1.5
Δ to previous year			0.0	0.0	0.0	0.0	-1.5					
SK	**Slovakia**											
EATR		16.8	16.8	20.3	19.6	18.7	18.7	18.5	16.8	20.3	3.5	1.9
Δ to previous year			0.0	3.4	-0.7	-0.9	0.0					
SI	**Slovenia**											
EATR		19.1	18.2	15.5	15.5	17.3	17.3	17.1	15.5	19.1	3.6	-1.8
Δ to previous year			-0.9	-2.7	0.0	1.8	0.0					
ES	**Spain**											
EATR		32.8	31.9	32.9	31.5	29.0	29.0	31.2	29.0	32.9	3.9	-3.8
Δ to previous year			-0.9	1.0	-1.4	-2.5	0.0					
SE	**Sweden**											
EATR		23.2	23.2	19.4	19.4	19.4	19.4	20.7	19.4	23.2	3.8	-3.8
Δ to previous year			0.0	-3.7	0.0	0.0	-0.1					
UK	**United Kingdom**											
EATR		28.3	26.9	24.3	21.5	20.5	20.2	23.6	20.2	28.3	8.1	-8.1
Δ to previous year			-1.5	-2.6	-2.8	-1.0	-0.3					

Appendix 2: Effective average tax rates on corporate investment, 2009-2019 (in %) (continued)

		2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
JP	**Japan**											
EATR		41.7	41.7	40.1	35.7	34.3	34.1	37.9	34.1	41.7	7.6	-7.6
Δ to previous year			0.0	-1.6	-4.4	-1.5	-0.2					
NO	**Norway**											
EATR		26.5	26.5	26.5	25.1	22.7	20.8	24.7	20.8	26.5	5.7	-5.7
Δ to previous year			0.0	0.0	-1.3	-2.4	-1.9					
CH	**Switzerland**											
EATR		18.7	18.7	18.6	18.6	18.6	18.6	18.6	18.6	18.7	0.1	-0.1
Δ to previous year			0.0	0.0	0.0	0.0	0.0					
US	**USA**											
EATR		37.4	36.5	36.5	36.5	36.5	27.5	35.2	27.5	37.4	9.9	-9.9
Δ to previous year			-0.9	0.0	0.0	0.0	-9.0					
BR	**Brazil**											
EATR		25.9	26.1	27.2	26.7	24.5	25.0	25.9	24.5	27.2	2.7	-0.9
Δ to previous year			0.3	1.1	-0.5	-2.2	0.5					
CN	**China**											
EATR		23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	0.0	0.0
Δ to previous year			0.0	0.0	0.0	0.0	0.0					
IN	**India**											
EATR		39.9	38.4	39.9	40.5	40.5	40.8	40.0	38.4	40.8	2.4	0.9
Δ to previous year			-1.5	1.5	0.6	0.0	0.3					
RU	**Russia**											
EATR		20.7	20.9	19.1	19.1	19.1	19.1	19.7	19.1	20.9	1.8	-1.6
Δ to previous year			0.2	-1.8	0.0	0.0	0.0					

Notes: Effective tax rates are calculated for a corporation of the manufacturing sector and under the assumption that the top corporate income tax rate is applicable. The table lists the effective tax rate for every second year and the delta to the previously reported effective tax burden. Deviation in Δ may result from rounding differences.

Source: based on Spengel et al. (2021), own calculation and illustration for BR, CN, IN, and RU.

Appendix 3: Labour taxation: Statutory tax rates and effective average tax rates at the employee level, 2009 and 2019

Labour	Statutory tax rates (%) [top income tax bracket, EUR]				EATR (%) [EUR 100’000]	
	2009		2019		2009	2019
EU member states						
Austria	50.0	[60’000]	55.0	[1’000’000]	38.3	41.3
Belgium	53.5	[34’330]	57.6	[40’480]	57.6	59.5
Czech	15.0	[1]	22.0	[49’315]	21.4	26.4
Denmark	57.8	[46’748]	50.9	[69’126]	51.9	44.1
Finland	48.0	[64’500]	49.3	[76’100]	52.7	52.2
France	40.0	[69’505]	45.0	[156’244]	46.6	42.0
Germany	47.5	[250’000]	47.5	[265’326]	40.6	39.8
Hungary	36.0	[6’732]	15.0	[1]	46.9	37.0
Ireland	41.0	[36’400]	43.2	[35’300]	42.0	48.6
Italy	44.9	[75’000]	45.5	[300’000]	52.7	52.5
Luxembourg	39.0	[39’885]	45.8	[200’004]	34.7	40.1
Netherlands	52.0	[54’776]	51.8	[68’507]	42.9	46.2
Poland	32.0	[19’505]	32.0	[19’505]	31.3	32.6
Slovakia	19.0	[1]	25.0	[36’256]	30.6	32.8
Slovenia	41.0	[14’821]	50.0	[70’907]	46.0	46.2
Spain	42.9	[53’407]	43.5	[60’000]	40.9	44.7
Sweden	54.7	[59’072]	54.8	[75’573]	53.6	56.2
UK	40.0	[54’839]	45.0	[219’941]	39.4	39.2
Third countries						
Japan	50.0	[121’990]	57.1	[271’089]	27.9	28.4
Norway	40.0	[89’710]	38.2	[120’781]	42.9	36.9
Switzerland	40.0	[486’016]	40.0	[515’211]	31.8	31.2
US	45.6	[1’061’571]	49.3	[608’259]	40.3	36.6
Brazil	27.5	[16’569]	27.5	[20’648]	40.1	39.8
China	45.0	[119’142]	45.0	[95’314]	39.7	42.0
India	41.2	[16’313]	46.8	[163’132]	37.0	36.3
Russia	13.0	[1]	13.0	[1]	15.3	16.3
Mean overall	40.6		42.1		40.2	40.3
Standard deviation	11.5		12.4		9.8	9.3
Mean EU member states	41.9		43.3		42.8	43.4
Standard deviation	11.4		12.0		9.1	8.3
Mean Third countries	37.8		39.6		34.4	33.4
Standard deviation	12.0		13.8		8.6	7.6

Source: own composition based on BAK Economics et al. (2020), own calculation for BR, IN, JP, RU for the year 2009.

Appendix 4: Effective average tax rates on highly skilled labour, 2009-2019 (in %)

		2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
AT	**Austria**											
EATR		38.3	38.4	40.2	40.3	41.2	41.3	40.0	38.3	41.3	3.0	3.0
Δ to previous year			0.1	1.8	0.1	0.9	0.1					
BE	**Belgium**											
EATR		57.6	57.8	56.6	60.7	60.5	59.5	58.8	56.6	60.7	4.1	1.9
Δ to previous year			0.2	-1.2	4.1	-0.2	-1.0					
CZ	**Czech Republic**											
EATR		21.4	24.9	25.6	25.6	25.8	26.4	25.0	21.4	26.4	5.0	5.0
Δ to previous year			3.5	0.7	0.0	0.2	0.6					
DK	**Denmark**											
EATR		51.9	50.9	47.3	46.9	45.8	44.1	47.8	44.1	51.9	7.8	-7.8
Δ to previous year			-1.0	-3.6	-0.4	-1.1	-1.7					
FI	**Finland**											
EATR		52.7	52.0	52.2	52.6	53.5	52.2	52.5	52.0	53.5	1.5	-0.5
Δ to previous year			-0.7	0.2	0.4	0.9	-1.3					
FR	**France**											
EATR		46.6	46.4	46.5	47.0	47.9	42.0	46.1	42.0	47.9	5.9	-4.6
Δ to previous year			-0.2	0.1	0.5	0.9	-5.9					
DE	**Germany**											
EATR		40.6	40.8	40.4	40.4	40.2	39.8	40.4	39.8	40.8	1.0	-0.8
Δ to previous year			0.2	-0.4	0.0	-0.2	-0.4					
HU	**Hungary**											
EATR		46.9	32.2	42.7	40.5	37.7	37.0	39.5	32.2	46.9	14.7	-9.9
Δ to previous year			-14.7	10.5	-2.2	-2.8	-0.7					
IE	**Ireland**											
EATR		42.0	48.6	49.4	49.0	46.6	48.6	47.4	42.0	49.4	7.4	6.6
Δ to previous year			6.6	0.8	-0.4	-2.4	2.0					

Appendix 4: Effective average tax rates on highly skilled labour, 2009-2019 (in %) (continued)

		2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
IT	**Italy**											
EATR		52.7	53.1	52.8	52.8	52.9	52.5	52.8	52.5	53.1	0.6	-0.2
Δ to previous year			0.4	-0.3	0.0	0.1	-0.4					
LU	**Luxembourg**											
EATR		34.7	39.8	40.5	41.3	40.1	40.1	39.4	34.7	41.3	6.6	5.4
Δ to previous year			5.1	0.7	0.8	-1.2	0.0					
NL	**Netherlands**											
EATR		42.9	43.5	44.8	46.4	46.1	46.2	45.0	42.9	46.4	3.5	3.3
Δ to previous year			0.6	1.3	1.6	-0.3	0.1					
PL	**Poland**											
EATR		31.3	31.3	31.8	32.0	32.3	32.6	31.9	31.3	32.6	1.3	1.3
Δ to previous year			0.0	0.5	0.2	0.3	0.3					
SK	**Slovakia**											
EATR		30.6	30.9	32.3	32.6	32.1	32.8	31.9	30.6	32.8	2.2	2.2
Δ to previous year			0.3	1.4	0.3	-0.5	0.7					
SI	**Slovenia**											
EATR		46.0	46.1	48.2	48.1	46.3	46.2	46.8	46.0	48.2	2.2	0.2
Δ to previous year			0.1	2.1	-0.1	-1.8	-0.1					
ES	**Spain**											
EATR		40.9	43.3	47.5	44.1	44.3	44.7	44.1	40.9	47.5	6.6	3.8
Δ to previous year			2.4	4.2	-3.4	0.2	0.4					
SE	**Sweden**											
EATR		53.6	56.2	56.4	55.6	56.9	56.2	55.8	53.6	56.9	3.3	2.6
Δ to previous year			2.6	0.2	-0.8	1.3	-0.7					
UK	**United Kingdom**											
EATR		39.4	42.6	41.8	41.6	40.5	39.2	40.9	39.2	42.6	3.4	-0.2
Δ to previous year			3.2	-0.8	-0.2	-1.1	-1.3					

Appendix 4: Effective average tax rates on highly skilled labour, 2009-2019 (in %) (continued)

		2009	2011	2013	2015	2017	2019	Mean	Min	Max	Δ Max-Min	Δ 2019-2009
JP	**Japan**											
EATR		27.9	27.7	28.1	28.1	28.1	28.4	28.1	27.7	28.4	0.7	0.5
Δ to previous year			-0.2	0.4	0.0	0.0	0.3					
NO	**Norway**											
EATR		42.9	42.4	41.3	40.1	40.2	36.9	40.6	36.9	42.9	6.0	-6.0
Δ to previous year			-0.5	-1.1	-1.2	0.1	-3.3					
CH	**Switzerland**											
EATR		31.8	31.8	31.2	31.1	31.3	31.2	31.4	31.1	31.8	0.7	-0.6
Δ to previous year			0.0	-0.6	-0.1	0.2	-0.1					
US	**USA**											
EATR		40.3	38.7	39.8	39.7	40.1	36.6	39.2	36.6	40.3	3.7	-3.7
Δ to previous year			-1.6	1.1	-0.1	0.4	-3.5					
BR	**Brazil**											
EATR		40.1	40.1	40.0	39.9	39.7	39.8	39.9	39.7	40.1	0.4	-0.3
Δ to previous year			0.0	-0.1	-0.1	-0.2	0.1					
CN	**China**											
EATR		39.7	39.7	41.7	43.3	43.5	42.0	41.7	39.7	43.5	3.8	2.3
Δ to previous year			0.0	2.0	1.6	0.2	-1.5					
IN	**India**											
EATR		37.0	35.4	36.1	35.7	36.0	36.3	36.1	35.4	37.0	1.6	-0.7
Δ to previous year			-1.6	0.7	-0.4	0.3	0.3					
RU	**Russia**											
EATR		15.3	15.9	15.9	15.3	15.7	16.3	15.7	15.3	16.3	1.0	1.0
Δ to previous year			0.6	0.0	-0.6	0.4	0.6					

Notes: Effective tax rates are calculated under the model assumption of a single employee with no children and a disposable income of EUR 100’000.
The table lists the effective tax rate for every second year and the delta to the previously reported effective tax burden. Deviation in Δ may result from rounding differences.
Source: own composition based on BAK Economics et al. (2020), own calculation for BR, IN, JP, RU for the years 2009-2013.

Appendix 5: Foreign exchange rates used for the calculation of the effective average tax rates on highly skilled labour, fixed for all years

		National currency	2009 - 2019
AT	Austria	EUR	1.000
BE	Belgium	EUR	1.000
CZ	Czech Republic	CZK	31.827
DK	Denmark	DKK	7.427
FI	Finland	EUR	1.000
FR	France	EUR	1.000
DE	Germany	EUR	1.000
HU	Hungary	HUF	252.525
IE	Ireland	EUR	1.000
IT	Italy	EUR	1.000
LU	Luxembourg	EUR	1.000
NL	Netherlands	EUR	1.000
PL	Poland	PLN	4.385
SK	Slovakia	EUR	1.000
SI	Slovenia	EUR	1.000
ES	Spain	EUR	1.000
SE	Sweden	SEK	9.121
UK	United Kingdom	GBP	0.682
JP	Japan	JPY	147.553
NO	Norway	NOK	7.988
CH	Switzerland	CHF	1.466
US	USA	USD	0.942
BR	Brazil	BRL	2.711
CN	China	CNY	10.072
IN	India	IND	61.300
RU	Russia	RUB	37.422

Notes: The exchange rates are given as EUR 1 = CZK 31.827. The years on which the fixed exchange rate is based depend on when the respective countries were included in the BAK-Taxation Index. For example, for Brazil, Russia, India, and Japan, it corresponds to the average exchange rate from 2006-2010.

Source: BAK Economics et al. (2020)

B. Appendix to Chapter 3

Appendix 6: Domestic digital transformation model vs. traditional business model

	Domestic digital transformation without incentives							
Measure:	**EATR**				**CoC**			
Country	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**
AT	24	0	20.2%	-2.9	31	-7	5.4%	-0.8
BE	28	2	24.8%	-4.6	5	19	4.8%	-1.4
BG	2	-1	7.2%	-1.8	12	-7	4.9%	-0.4
CA	21	6	19.0%	-5.2	17	10	5.1%	-1.3
CH	18	-5	16.1%	-2.6	16	-5	5.1%	-0.7
CY	1	2	7.1%	-5.9	4	-1	4.5%	-0.8
CZ	11	-1	14.1%	-2.6	13	-6	5.0%	-0.6
DE	27	2	23.7%	-5.1	15	13	5.0%	-1.5
DK	12	7	14.4%	-5.6	3	16	4.5%	-1.4
EE	15	-6	15.7%	0.0	22	-20	5.2%	0.0
ES	29	2	25.2%	-4.9	33	-1	6.0%	-1.1
FI	17	-1	16.0%	-3.6	26	-3	5.2%	-0.9
FR	30	3	27.0%	-6.4	21	12	5.1%	-2.0
GR	26	2	22.8%	-4.8	28	2	5.3%	-1.3
HR	8	0	12.6%	-2.2	6	-2	4.8%	-0.5
HU	3	-1	9.2%	-1.9	24	-15	5.2%	-0.5
IE	4	1	10.1%	-4.0	23	-14	5.2%	-0.5
IT	9	16	12.9%	-10.6	1	16	2.8%	-3.1
JP	32	2	30.5%	-3.8	35	0	7.0%	-1.1
LT	6	-2	10.8%	-2.9	9	-3	4.9%	-0.7
LU	23	3	19.7%	-4.0	7	13	4.8%	-1.1
LV	5	1	10.7%	-3.6	8	3	4.9%	-0.8
MT	31	1	27.2%	-5.1	27	4	5.3%	-1.6
NL	22	0	19.6%	-3.0	25	-4	5.2%	-0.8
NO	25	-2	21.9%	-0.8	34	-8	6.0%	-0.2
PL	10	2	13.8%	-3.7	10	5	4.9%	-0.9
PT	20	-3	18.1%	-2.0	2	-1	3.9%	-0.6
RO	7	0	11.7%	-3.0	11	-3	4.9%	-0.7
SE	19	-4	16.4%	-3.0	20	-4	5.1%	-0.8
SK	13	1	15.5%	-3.2	29	-16	5.3%	-0.4
SL	16	-5	15.8%	-1.5	14	-1	5.0%	-0.7
UK	14	6	15.7%	-4.8	30	-1	5.4%	-1.2
US	33	2	30.8%	-5.7	32	2	5.8%	-1.8
Average			**17.5%**	**-3.8**			**5.1%**	**-1.0**

Notes: This table presents the EATR and CoC for the domestic (standard) investment in the digital transformation for the 33 countries considered in this study. Thus, it only includes provisions to determine the tax base for the digital investment asset. As a reference category we use the ranking for the traditional manufacturing scenario.

Source: Own calculation and composition, Spengel et al. (2018).

Appendix 7: Domestic digital transformation model vs. considering R&D tax incentives

	Domestic digital transformation with R&D tax incentives							
Measure:	**EATR**				**CoC**			
Country	**Rank**	**ΔRank**	**Ø**	**Δ in pp**	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**
AT	23	1	15.2%	-5.0	23	6	4.0%	-1.3
BE	30	-2	21.2%	-3.6	19	-14	3.7%	-1.1
BG	12	-10	7.2%	0.0	28	-16	4.9%	0.0
CA	19	2	12.7%	-6.2	16	1	3.4%	-1.7
CH	26	-8	16.1%	0.0	30	-14	5.1%	0.0
CY	11	-10	7.1%	0.0	25	-21	4.5%	0.0
CZ	8	3	6.1%	-8.0	12	1	3.0%	-2.0
DE	33	-6	23.7%	0.0	29	-14	5.0%	0.0
DK	22	-10	14.4%	0.	24	-21	4.5%	0.0
EE	24	-9	15.7%	0.0	32	-12	5.2%	0.0
ES	9	20	6.2%	-19.0	3	28	0.0%	-6.0
FI	25	-8	16.0%	0.0	33	-9	5.2%	0.0
FR	15	15	8.7%	-18.3	2	17	-0.5%	-5.7
GR	28	-2	17.1%	-5.7	21	5	3.7%	-1.6
HR	6	2	3.2%	-9.4	10	-4	2.5%	-2.3
HU	5	-2	-0.8%	-10.0	11	11	2.9%	-2.3
IE	2	2	-4.6%	-14.7	6	15	1.8%	-3.4
IT	1	8	-32.8%	-45.7	1	0	-9.9%	-12.6
JP	31	1	22.3%	-8.2	26	7	4.6%	-2.4
LT	3	3	-2.1%	-12.8	7	2	1.9%	-3.0
LU	29	-6	19.7%	0.0	27	-20	4.8%	0.0
LV	4	1	-1.9%	-12.6	8	0	1.9%	-3.0
MT	21	10	14.3%	-12.9	5	20	1.3%	-4.0
NL	20	2	12.9%	-6.7	17	6	3.4%	-1.8
NO	13	12	7.5%	-14.4	9	23	2.2%	-3.8
PL	14	-4	8.7%	-5.2	18	-8	3.6%	-1.3
PT	10	10	7.1%	-11.0	4	-2	0.7%	-3.1
RO	7	0	3.8%	-7.8	13	-2	3.1%	-1.9
SE	27	-8	16.4%	0.0	31	-13	5.1%	0.0
SK	16	-3	8.9%	-6.6	20	7	3.7%	-1.6
SL	18	-2	9.4%	-6.4	15	-1	3.4%	-1.6
UK	17	-3	9.3%	-6.4	22	6	3.8%	-1.6
US	32	1	22.6%	-8.2	14	16	3.1%	-2.6
Average			**9.4%**	**-8.0**			**2.9%**	**-2.2**

Notes: This table presents the EATR and CoC for the domestic investment in the digital transformation including existing (input-oriented) R&D tax incentives for the 33 countries considered in this study. As a reference category we use the ranking for the standard digital transformation scenario.
Source: Own calculation and composition.

Appendix 8: Domestic digital transformation model vs. considering IP boxes

	Domestic digital transformation with IP boxes							
Measure:	**EATR**				**CoC**			
Country	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**
AT	25	-1	20.2%	0.0	28	1	5.4%	0.0
BE	17	-11	15.6%	-9.2	5	0	4.8%	0.0
BG	2	0	7.2%	0.0	11	-1	4.9%	0.0
CA	24	3	19.0%	0.0	17	0	5.1%	0.0
CH	21	3	16.1%	0.0	16	0	5.1%	0.0
CY	1	0	7.1%	0.0	4	0	4.5%	0.0
CZ	13	2	14.1%	0.0	12	-1	5.0%	0.0
DE	28	1	23.7%	0.0	14	-1	5.0%	0.0
DK	15	3	14.4%	0.0	3	0	4.5%	0.0
EE	18	3	15.7%	0.0	20	0	5.2%	0.0
ES	29	0	25.2%	0.0	31	0	6.0%	0.0
FI	20	3	16.0%	0.0	24	0	5.2%	0.0
FR	30	0	27.0%	0.0	19	0	5.1%	0.0
GR	27	1	22.8%	0.0	26	0	5.3%	0.0
HR	11	3	12.6%	0.0	6	0	4.8%	0.0
HU	6	3	9.2%	0.0	21	-1	5.2%	0.0
IE	4	0	8.5%	-1.6	23	2	5.2%	0.1
IT	5	-4	9.0%	-3.9	1	0	2.9%	0.1
JP	32	0	30.5%	0.0	33	0	7.0%	0.0
LT	8	2	10.8%	0.0	8	-1	4.9%	0.0
LU	3	-20	7.5%	-12.3	15	8	5.0%	0.2
LV	7	2	10.7%	0.0	7	-1	4.9%	0.0
MT	31	0	27.2%	0.0	25	0	5.3%	0.0
NL	14	-8	14.2%	-5.3	29	6	5.4%	0.2
NO	26	1	21.9%	0.0	32	0	6.0%	0.0
PL	12	2	13.8%	0.0	9	-1	4.9%	0.0
PT	23	3	18.1%	0.0	2	0	3.9%	0.0
RO	9	2	11.7%	0.0	10	-1	4.9%	0.0
SE	22	3	16.4%	0.0	18	0	5.1%	0.0
SK	16	3	15.5%	0.0	27	0	5.3%	0.0
SL	19	3	15.8%	0.0	13	-1	5.0%	0.0
UK	10	-4	12.4%	-3.3	22	-6	5.2%	-0.1
US	33	0	30.8%	0.0	30	0	5.8%	0.0
Average			**16.4%**	**-1.1**			**5.1%**	**0.0**

Notes: This table presents the EATR and CoC for the domestic investment in the digital transformation including existing (output-oriented) R&D tax incentives for the 33 countries considered in this study. As a reference category we use the ranking for the standard digital transformation scenario.
Source: Own calculation and composition.

Appendix 9: Domestic digital transformation model vs. considering R&D tax incentives and IP boxes

	Domestic digital transformation with IP boxes							
Measure:	**EATR**				**CoC**			
Country	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**	**Rank**	**Δ Rank**	**Ø**	**Δ in pp**
AT	25	-1	15.2%	-5.0	23	6	4.0%	-1.3
BE	21	-7	12.0%	-12.8	21	16	3.9%	-0.9
BG	13	11	7.2%	0.0	27	15	4.9%	0.0
CA	22	1	12.7%	-6.2	16	-1	3.4%	-1.7
CH	28	10	16.1%	0.0	30	14	5.1%	0.0
CY	12	11	7.1%	0.0	25	21	4.5%	0.0
CZ	9	-2	6.1%	-8.0	12	-1	3.0%	-2.0
DE	33	6	23.7%	0.0	28	13	5.0%	0.0
DK	24	12	14.4%	0.0	24	21	4.5%	0.0
EE	26	11	15.7%	0.0	32	12	5.2%	0.0
ES	10	-19	6.2%	-19.0	3	-28	0.0%	-6.0
FI	27	10	16.0%	0.0	33	9	5.2%	0.0
FR	18	-12	8.7%	-18.3	2	-17	-0.5%	-5.7
GR	30	4	17.1%	-5.7	19	-7	3.7%	-1.6
HR	6	-2	3.2%	-9.4	10	4	2.5%	-2.3
HU	5	2	-0.8%	-10.0	11	-11	2.9%	-2.3
IE	2	-2	-6.3%	-16.4	8	-13	2.0%	-3.2
IT	1	-8	-37.0%	-49.8	1	0	-8.9%	-11.7
JP	31	-1	22.3%	-8.2	26	-7	4.6%	-2.4
LT	3	-3	-2.1%	-12.8	6	-3	1.9%	-3.0
LU	15	-8	7.5%	-12.3	29	22	5.0%	0.2
LV	4	-1	-1.9%	-12.6	7	-1	1.9%	-3.0
MT	23	-8	14.3%	-12.9	5	-20	1.3%	-4.0
NL	14	-8	7.4%	-12.1	22	-1	4.0%	-1.2
NO	16	-9	7.5%	-14.4	9	-23	2.2%	-3.8
PL	17	7	8.7%	-5.2	17	7	3.6%	-1.3
PT	11	-9	7.1%	-11.0	4	2	0.7%	-3.1
RO	7	0	3.8%	-7.8	13	2	3.1%	-1.9
SE	29	10	16.4%	0.0	31	13	5.1%	0.0
SK	19	6	8.9%	-6.6	18	-9	3.7%	-1.6
SL	20	4	9.4%	-6.4	15	1	3.4%	-1.6
UK	8	-6	6.0%	-9.7	20	-8	3.7%	-1.7
US	32	-1	22.6%	-8.2	14	-16	3.1%	-2.6
Average			**8.3%**	**-9.1**			**3.0%**	**-2.1**

Notes: This table presents the EATR and CoC for the domestic investment in the digital transformation including existing R&D tax incentives for the 33 countries considered in this study. As a reference category we use the ranking for the standard digital transformation scenario.

Source: Own calculation and composition.

Appendix 10: Tax depreciation provisions for (capitalized) software (in %) as of 1 July 2017 (in %)

Country	Classification / Description	Depreciation Method	Depreciation Rate
AT	None, like movable assets	-	-
BE	None, like movable assets	-	-
BG	Software and right of use for software	SL	50
CA	System software for data networks and data processing, other computer software	DB	30
CH	Software	DB	40
CY	Operating software/ application software up to EUR 1.708,60/ application software from EUR 1.708,60	SL / immediate / SL	20/ 100 / 33.3
CZ	Software	SL	33.3
DK	Computer software	immediate	100
DE	(acquired standard-) software	SL	33.3
EE	None, like movable assets	-	-
ES	Software	SL	33.3
FI	None, like movable assets	-	-
FR	None, like movable assets	-	-
GR	Software	SL	20
HR	Software	SL	50
HU	None, like movable assets	-	-
IE	None, like movable assets	-	-
IT	Software, systems, platform software	SL	140
JP	None, like movable assets	-	-
LV	Software products	DB	70
LT	(acquired) software	SL	33.3
LU	None, like movable assets	-	-
MT	Computer software	SL	25
NL	None, like movable assets	-	-
NO	None, like movable assets	-	-
PL	Computer software	SL	50
PT	Software	SL	33.3
RO	Software	SL	33.3
SE	None, like movable assets	-	-
SK	Software, intangible assets	SL	20
SL	Computer software	SL	50
UK	None, like movable assets	-	-
US	Computer software	SL	33.3

Notes: SL – straight-line; DB – declining balance
Source: own composition and illustration, IBFD, Spengel et al. (2018)

Appendix 11: Tax depreciation provisions for (capitalized) hardware (in %) as of 1 July 2017 (in %)

Country	Classification / Description	Depreciation Method	Depreciation Rate
AT	none, like movable assets	-	-
BE	none, like movable assets	-	-
BG	Computer and equipment	SL	50
CA	Computer	DB	55
CH	Computer hardware	DB	40
CY	Computer	SL	20
CZ	Computer hardware	SL	20/40/40
DK	Computer hardware	Immediate[a]	100
DE	Computer and equipment	SL	
EE	none, like movable assets	-	-
ES	Computer hardware	SL	25
FI	none, like movable assets	-	-
FR	none, like movable assets	-	-
GR	Computer and equipment	SL	20
HR	Computer and network equipment	SL	50
HU	Computer and equipment	SL	50
IE	none, like movable assets	-	-
IT	High-tech[b]	Additional	250
JP	none, like movable assets	-	-
LV	Computer and other hardware	DB	70
LT	none, like movable assets	-	-
LU	none, like movable assets	-	-
MT	Computer and electronic equipment	SL	25
NL	none, like movable assets	-	-
NO	Computer	DB	30
PL	Computer	SL	30
PT	Computer	SL	33.3
RO	Computer and equipment	Accelerated	50[c]
SE	none, like movable assets	-	-
SK	Computer and printer	SL	25
SL	Computer and equipment	SL	50
UK	none, like movable assets	-	-
US	Computer and equipment	SL	20

Notes: SL – straight-line; DB – declining balance; [a] immediate deduction, however if hardware and software are used in conjunction and costs are above DKK 13’200, capitalization required and SL with 25%; [b] applied to high-tech, cloud, ultra-broadband industrial robotics, digital manufacturing, IT security, etc.; [c] in the first year, plus two additional years (year 2 and 3: each 25%); [d] 20% in the first year, 40% in year 2 and 3
Source: own composition and illustration, IBFD, Spengel et al. (2018)

Appendix 12: R&D tax incentives and applicability to digital investment assets as of 1 July 2017 (in %)

Country	Incentive scheme	Incentive rate	Acq. IP	Acq. software	Self.-dev. IP	Self.-dev. software	Hardware
AT	credit	12			✓	✓	
BE	credit	4.59	✓	✓	✓	✓	✓
CA	credit	15			✓	✓	
CZ	enhanced deduction	200			✓	✓	
DK	immediate deduction	100	✓	✓	✓	✓	✓
ES	credit	25/42/8[j]			✓	✓	✓
FR	credit	30[a]	✓	✓	✓	✓	✓
GR	enhanced deduction	130			✓	✓	✓
HR	enhanced deduction	225			✓	✓	
HU	enhanced deduction[b]	200	✓	✓	✓	✓	✓
IE	credit	25			✓	✓	✓
IT	credit[c]	50	✓	✓	✓	✓	✓
JP	credit	14			✓	✓	✓
LV	enhanced deduction	300			✓	✓	
LT	enhanced deduction	300			✓	✓	(✓)[d]
MT	enh. deduction/ credit[e]	150/15		✓	✓	✓	✓
NL	credit	16			✓	✓	
NO	credit[f]	18	✓	✓	✓	✓	✓
PL	enhanced deduction	150/130[g]			✓	✓	✓
PT	credit	32.5[h]			✓	✓	
RO	enhanced deduction	150	✓	✓	✓	✓	✓
SK	enhanced deduction	125/150[i]			✓	✓	✓
SL	enhanced deduction	200			✓	✓	
UK	credit	11		✓	✓	✓	
US	credit[c]	20			✓	✓	

Notes: [a] 50% of R&D personnel costs, 75% for depreciation of used assets; [b] assumption of capitalized R&D expenses for the applicable investment assets; [c] incremental incentive; [d] additional accelerated depreciation for hardware over 2 years; [e] additional capital allowance for self-developed intangible assets and software, credit for acquired software and hardware; [f] limited to 25 million NOK; [g] 150% deduction for personnel expenses, 130% deduction for depreciation of assets; [h] 32.5% volume, 50% incremental capped at EUR 1.5 million; [i] 125% (volume) + 25% (incremental); [j] 25% (volume) respectively 42% (incremental) for self-developed intangible assets and self-developed software (assumption: mix of personnel and other costs), 8% for hardware (assumption: investment costs).

Source: own composition and illustration, IBFD.

Appendix 13: IP box regimes and applicability to digital investment assets as of 1 July 2017 (in %)

		Qualifying assets				Qualifying income				Treatment of expenses	
Country	**IP box tax rate**	**Acq. IP**	**Acq. software**	**Self.-dev. IP**	**Self.-dev. software**	**Revenue**	**Licenses**	**Notional licenses**	**Capital gains**	**Current expense**	**Historical expenses**
BE	5.10			✓	✓	✓	✓		✓	net	no recapture
CH	2.5			✓	✓		✓		✓	net	no recapture
CY	16.76			✓	✓		✓	✓	✓	net	addition[a]
ES	5.55			✓			✓		✓	net	no recapture
FR	6.25	✓		✓			✓		✓	net	no recapture
HU	13.91	✓	✓	✓	✓		✓	✓	✓	gross	no recapture
IE	5.42			✓	✓	✓	✓			net	no recapture
IT	0.00			✓	✓	✓	✓	✓	✓[b]	net	no recapture
LU	5.00	✓	✓	✓	✓	✓	✓	✓[c]	✓	net	addition[d]
MT	14.75	✓	✓	✓	✓		✓			gross	addition[e]
NL	15.63			✓	✓	✓	✓	✓	✓	net	addition
PT	2.53			✓			✓		✓	gross	no recapture
UK	10.00	✓		✓		✓	✓	✓	✓	net	addition[f]

Notes: [a] capitalization of development costs (subject to regular tax system); [b] exemption in case of reinvestment; [c] for self-developed IP; [d] capitalization and depreciation, clause for additional taxation of previously deducted operating expenses in case of realization of capital gains; [e] income does not benefit from IP box when R&D expenses have been deducted; [f] allocated to profits from intangible assets (streaming).
Source: own composition and illustration, IBFD, Evers (2015), Spengel et al. (2018)

C. Appendix to Chapter 4

Appendix 14: Corporate Income Tax, Capital and Real Estate Taxes 2020 (in %)

Country	Combined Effective Corporate Income Tax	Effective Net Worth Tax	Effective Real Estate Tax
Belgium	25	-	1.51
Switzerland (Zurich)	21.15	-	0.14
Germany	31.61	-	0.34
France	33.04	-	2.67
United Kingdom	19.00	-	2.07
Ireland	12.50	-	0.18
Netherlands	25.00	-	0.19
Spain	30.63	-	0.33
USA (California)	27.98	0.72 (Machinery)	0.72
China	25	-	0.72

Source: Updated parameters in line with Spengel et al. (2020) based on IBFD

Appendix 15: Depreciations and Valuation of Inventories 2020 (in %)

Country	Buildings			Machinery			Inventories
	Method	Rate (%)	Duration	Method	Rate (%)	Duration	
Belgium	SL	5.00	ufd	SL	10.00	ufd	LIFO
Switzerland (Zurich)	DB	8.0	ufd	-	80.0	1	LIFO
				-	0.0	5	
				-	20.0	7	
Germany	SL	3.00	ufd	SL	14.29	ufd	LIFO
France	SL	5.00	ufd	DB	32.14	4	Average
				SL	7.07	3	
United Kingdom	SL	3.00	ufd	DB	18.00	ufd	FIFO
Ireland	SL	4.00	ufd	SL	12.50	8	Average
Netherlands	SL	2.50	ufd	SL	14.29	7	LIFO
Spain	SL	3.00	ufd	DB	24.00	3	Average
				SL	11.00	4	
USA (California)	SL	2.46	1	DB	14.29	1	LIFO
	SL	2.56	38	DB	24.49	3	
	SL	0.11	1	SL	8.92	ufd	
China	SL	5.00	ufd	SL	10.00	10	Average

Notes: SL = straight line, DB = declining balance, ufd = until fully depreciated
Source: Updated parameters in line with Spengel et al. (2020) based on IBFD

Appendix 16: Gross domestic expenditure on R&D by type of expenditure as of 2017

Country	GERD[a]	Ratios (in %)				
	Total	Current	Capital [b]			
		Total	Total	Buildings	Machinery	Other
Belgium	10’037.200	91.1	8.9	1.4	4.9	2.6
France	40’425.233	87.4	12.6	0.6	5.4	6.6
Germany	86’077.667	92.5	7.5	.	.	.
Ireland	3’332.286	90.0	10.0	3.0	4.3	2.7
Netherlands	12’946.665	92.1	7.9	2.6	2.8	2.5
Spain	11’441.366	94.3	5.7	0.6	3.7	1.4
Switzerland (Zurich)	12’787.147	94.4	5.6	1.0	3.6	1.0
United Kingdom	32’842.639	91.5	8.5	1.8	6.7	0.0
USA (California)	388’639.847	100.0	0.0	.	.	.
China	333’883.83	90.3	9.7	0.2	9.5	0.0
AVERAGE						
Sample	93’241.388	91.5	8.5	.	.	.
OECD	25’912.822	95.0	5.0	.	.	.

Notes: [a] in constant prices and PPPs (2015 Dollars); [b] for some countries a detailed overview of the specific sub-type of expenditure is not available.
Source: OECD.Stat (2021). “Gross domestic expenditure on R&D by sector of performance and type of expenditure“.

Appendix 17: Comparison of different Scenarios: High and low inflation / interest & debt/equity (in %)

Country	Baseline - No incentive	Input incentive	IP box	Input incentive & IP box
Higher inflation / interest scenario - retained earnings				
Belgium	19.67	19.07	2.95	2.86
Switzerland (Zurich)	17.14	10.19	8.01	7.18
China	19.67	1.29	1.29	1.29
Germany	24.91	2.01	24.91	2.01
Spain	24.15	-34.45	12.56	-43.85
France	25.71	-8.17	9.08	-2.81
Ireland	9.84	-15.81	-6.93	-26.26
Netherlands	19.74	19.74	5.53	5.53
UK	15.03	3.39	7.57	-3.42
US (California)	22.06	3.74	22.06	3.74
Higher inflation / interest scenario - retained earnings				
Belgium	12.93	12.33	1.69	1.6
Switzerland (Zurich)	10.58	4.19	0.59	-0.18
China	12.93	-3.99	12.93	-3.99
Germany	18.02	-2.71	18.02	-2.71
Spain	17.85	-36.13	8.68	-45.32
France	17.88	-12.56	5.45	-6.06
Ireland	5.97	-18.69	-8.86	-27.7
Netherlands	13.00	13	3.25	3.25
UK	9.55	-1.38	4.4	-6.21
US (California)	14.77	-1.79	14.77	-1.79
Lower inflation / interest scenario - debt				
Belgium	20.23	19.83	2.94	2.88
Switzerland (Zurich)	17.07	11.4	5.96	5.28
China	20.23	4.82	20.23	4.82
Germany	26.28	7.61	26.28	7.61
Spain	25.69	-22.41	13.12	-34
France	27.01	-0.94	9.2	-1.16
Ireland	9.94	-11.48	-6.63	-21.43
Netherlands	20.31	20.31	5.53	5.53
UK	15.30	5.91	7.78	-1.44
US (California)	22.82	7.89	22.82	7.89

Notes: In the higher inflation and interest scenario, we rely on an inflation of 2% and a real interest rate of 5% based on Spengel et al. (2021). We use an inflation rate of 0.73% and a real interest rate of 2% in the lower inflation and interest scenario.
Source: own calculation

Appendix 18: Sensitivity to country-specific composition of R&D expenses for selected countries (in %)

Lower inflation / interest scenario - retained earnings				
Country	**No incentive**	**Input incentive**	**IP box**	**Input incentive & IP box**
Switzerland (Zurich)	19.85 (-0.14)	13.93 (-0.13)	9.19 (-0.06)	8.48 (-0.06)
Spain	28.16 (0.00)	-23.16 (-1.40)	14.49 (-0.15)	-35.13 (-1.71)
France	30.07 (-0.01)	4.43 (3.65)	10.63 (0.00)	-0.40 (-0.51)

Notes: The composition is based on the gross domestic expenditure on R&D by type of expenditure as of 2017. However, the observed spending on machinery and buildings does not fully reflect capital investment spending. Since other expenses include software and purchased intangibles, we allocate most of the missing expenses to machinery for our calculation. We use the following composition of R&D expenses for the selected countries (current expenses, buildings, machinery): France (87/2.17/10.83), Switzerland (94/1/5) and Spain (94/1/5). The deviation to our baseline scenarios is stated in parentheses.
Source: own calculation

D. Appendix to Chapter 5

Appendix 19: Basic formulas of the Devereux-Griffith methodology to incorporate IP boxes

For the purpose of determining the impact of the nexus on the effective tax rates of corporations located in IP box jurisdictions within the Devereux-Griffith methodology, we follow the approach of Evers et al. (2015). We refer to an R&D investment giving rise to a self-developed patent (corporate level only).

The EATR is used as a measure to estimate the impact of the introduction of the nexus on investment location decisions and on tax planning strategies. It is computed as the difference of the NPV before and after taxes (denoted by R^* and R^t), divided by the discounted pre-tax rate of return p (assumed to be 20%):

$$EATR = (R^* - R^t)/\left(\frac{p}{1+r}\right) \tag{A1}$$

$$R^* = \frac{p-r}{1+r} \tag{A2}$$

To derive the economic rent of the project in the presence of tax (R^t), we model our patent investment as follows: In the first period, the company faces a temporary increase of the capital stock of one unit which is subject to the present value of depreciation allowances (A) according to national tax laws. In this way, parts of the income from the investment are exempted from taxation, i.e., the effect of a tax shield is achieved. In the second period, the investment generates a real financial return of p and a one period cost of depreciation δ. In addition, the income grows with the inflation rate (π), and is subject to corporate income tax at rate τ. To return to its initial level, the capital stock is reduced by $(1-\delta)(1+\pi)$.

$$R^t = \underbrace{-(1-A)}_{\substack{\textit{R\&D expenses,}\\ \textit{tax depreciation}}} + \underbrace{(1-\tau)\frac{(p+\delta)(1+\pi)}{1+i}}_{\substack{\textit{Returns generated}\\ \textit{by a patent}}} + \underbrace{(1-A)\frac{(1-\delta)(1+\pi)}{1+i}}_{\substack{\textit{Reduction}\\ \textit{in capital stock}}} + \underbrace{F}_{\substack{\textit{Financing}\\ \textit{term}}} \tag{A3}$$

In calculating the NPV of a net income stream, companies are assumed to discount income in the second period in line with the nominal capital market interest rate, i.[156]

In Eq. (A4) the first term with the share of immediately deductible expenses, φ_0 (regularly 100%), represents the immediate written-off R&D expenses. The second term denotes the capitalization of the R&D expenses, which compensates for the immediate depreciation. We

[156] It is assumed, as is standard, that the real (r) and nominal interest rates (i) are related as follows: $(1+i) = (1+r)(1+\pi)$.

follow Evers et al. (2015) and assume for simplicity that both processes concern one period, and hence, the two terms balance out each other. As a consequence, we do not consider any timing effects resulting from the fact that R&D expenses remain deductible until a self-developed intangible asset is created. In the case of capitalization, A reflects the NPV of the periodic depreciation, which is composed of the depreciation rate φ over the useful life (l). In the absence of capitalization, the tax allowance corresponds to the immediate depreciation of the R&D expenses (term 1), with which $A = \varphi_0\tau = \tau$ applies.

$$A = \underbrace{\varphi_0\tau}_{\textit{Immediate Expense}} - \underbrace{\varphi_0\tau}_{\textit{Capitalization}} + \underbrace{\varphi\tau\left\{\left(\frac{1}{1+i}\right)^1 + \cdots + \left(\frac{1}{1+i}\right)^l\right\}}_{\textit{Periodical Depreciation (M, B)}} \tag{A4}$$

To consider other financing possibilities than retained earnings, R must be modified by an additional financing term F. If companies finance their R&D investment via retained earnings, the initial investment reduces the funds which are available for distribution. This is reflected by the first term of Eq. (A3). In contrast, the financing of the investment with debt, allows the distribution of these funds in the initial period (Eq. (A6) first term). However, then the distribution in the second period is reduced by the amount of the loan repayment and the nominal interest expenses. In all countries, interest expenses are deductible from the corporate income tax base, thus shielding the marginal return from profit taxation. The value of this tax shield is determined by the product of the profit tax rate and the nominal interest rate (see second term of equation A6). For the same reason, we have to add a financing term, if we consider notional income deductions in equity-financed R&D investments (depicted by equation A7). If the (notional) interest deduction equals the capital market interest rate, the marginal return is fully shielded from profit taxation.

Retained earnings (RE)

$$F^{RE} = 0 \tag{A5}$$

Debt (D)

$$F^{D} = (1-\tau\varphi_0) - \frac{(1-\tau\varphi_0)\big(1+i(1-\tau)\big)}{1+i} \tag{A6}$$

NID Adjustment

$$F^{NID} = \frac{(1-\tau\varphi_0)\tau i_{NID}}{1+i} \tag{A7}$$

To incorporate the IP box regimes into the effective tax measures, we substitute the regular corporate income tax rate τ with the preferential IP box tax rate τ_{IP}.

Appendix 20: Parameters of Devereux-Griffith Methodology

Economic parameters	
True economic depreciation rate of intangibles (%)	15.35
real interest rate (%)	5
inflation rate (%)	2
pre-tax rate of return for EATR (%)	20
Weighting of investment (%)	
current expenses	100

Source: Assumptions based on Spengel et al. (2021), Evers et al. (2015)

Appendix 21: Derivation of the modified IP tax rate for a given IP box tax rate

The tax liability (T) for a given IP box tax rate is given by:

$$T = \tau_{IP}\left(\frac{\min(1{,}3 \times E_{qualified}, E_{overall})}{E_{overall}} \times I_{overall}\right) + \tau\left(I_{overall} - \frac{\min(1{,}3 \times E_{qualfied}, E_{overall})}{E_{overall}} \times I_{overall}\right)$$

To simplify: $\frac{\min(1{,}3\times E_{qualified}, E_{overall})}{E_{overall}} \times I_{overall} = \varphi_{IP}$

$$T = \tau_{IP} \times \varphi_{IP} \times I_{overall} + \tau \times (I_{overall} - \varphi_{IP} \times I_{overall})$$

$$T = \tau_{IP} \times \varphi_{IP} \times I_{overall} + \tau \times I_{overall} - \tau \times \varphi_{IP} \times I_{overall}$$

$$T = I_{overall}[(\tau_{IP} \times \varphi_{IP}) + \tau - \tau \times \varphi_{IP}]$$

Since the tax liability is generally calculated by multiplying the tax rate by the taxable income, i.e., $T = \tau \times I_{overall}$, it follows that:

$$T/I_{overall} = \tau_{IP\ nexus} = [(\tau_{IP} \times \varphi_{IP}) + \tau - \tau \times \varphi_{IP}]$$

$$\tau_{IP\ nexus} = (\tau_{IP} - \tau) \times \varphi_{IP} + \tau$$

Assumption: $I_{overall} = \frac{(p+\delta)(1+\pi)}{1+i}$

If a company has less than 76.92% of qualifying IP expenditures, the applicable nexus tax rate is increasing in the amount of regularly taxed IP income.

Appendix 22: (Considered) R&D tax incentives in IP box states as of 2021

	Tax incentive	Incentive rate	Qualifying expenditures [a]	Carry forward	Limitation
BE	Immediate deduction	100%	Current	.	.
	R&D tax credit/ super deduction	13.5% (one-shot); 20.5% (spread) [b]	Capitalized R&D expenses	4 years	.
CY	Immediate deduction	100%	Current	.	.
FR	Immediate deduction	100%	Current	.	.
	R&D tax credit	30% (below EUR 100 million); 5% (above EUR 100 million)	Current, depreciation	3 years; refund afterwards	
HU	Immediate deduction	100%	Current	.	.
	Super deduction	100%	Current	5 years	≤ HUF 50 million per year
IE	Immediate deduction	100%	Current	.	.
	R&D tax credit	25%	Current	1 year carry back; indefinitely carry forward/refund over 33 months	Cap of refund: max(amount payroll taxes in the current and previous accounting period, CIT paid in the 10 preceding accounting periods)
IT	Immediate deduction	100%	Current		
	R&D tax credit	12% 6%	Current, intangibles	Indefinitely	≤ EUR 3 million per year ≤ EUR 1.5 million per year
LT	Immediate deduction	100%	Current	.	.
	Super deduction	200%	Current	Indefinitely	.
LU	Immediate deduction	100%	Current	.	.
MT	Immediate deduction	100%	Current	.	.
	R&D tax credit [c]	25%	Current	Indefinitely	≤ EUR 15 million per project
NL [d]	Immediate deduction	100%	Current	1 year carry back; 6 years carry forward	
PL	Immediate deduction	100%	Current	.	.
	Super deduction	100%	Current	6 years	.

Appendix 22: (Considered) R&D tax incentives in IP box states as of 2021 (continued)

	Tax incentive	Incentive rate	Qualifying expenditures [a]	Carry forward	Limitation
PT	Immediate deduction	100%	Current	.	.
	R&D tax credit	32.5% (volume) 50% (incremental)	Current, intangibles	8 years	. ≤ EUR 1.5 million
SK	Immediate deduction	100%	Current	.	.
	Super deduction	200% (volume) 100% (incremental)	Current	5 years	.
ES	Immediate deduction	100%	Current	.	.
	R&D tax credit	25% (volume) 42% (incremental) 8%	Current intangibles	18 years; refund (optional): 1 year after the tax credit generation (20% discount)	If R&D tax credits for the fiscal year exceed 10% of the tax due, the tax credits may offset up to 50% of the gross tax due. Otherwise, the tax credits may offset only up to 25% of the gross tax due.
CH	Immediate deduction	100%	Current	.	.
	Super deduction [e]	50%	Current (labour+35% uplift)		Relief limitation to 70% of the income before special deductions (e.g., enhanced deduction, IP box deduction, NID)
UK	Immediate deduction	100%	Current	.	.
	R&D tax credit (taxable)	13% [f]	Current, intangibles	Indefinite	.

Notes: [a] We only consider R&D tax incentives available for current R&D expenses and/or capitalized intangible assets. [b] In case of patents, only the one-shot deduction is available. [c] This scheme shall have a budget of five million euro per annum (€5,000,000) and an overall budget of twenty million euro (€20,000,000). [d] As the R&D Wage WHT Reduction is redeemable against payroll WHT, we do not consider its application in our estimations. [e] The super deduction is only available on the cantonal level. [f] As the British R&D tax credit is taxable, the value of the tax credit is reduced to 10.53% (=13%*(1-19%)).

Appendix 23: Sensitivity of the effective average tax burden by variations of the nexus ratio (%)

	BE	CH	CY	ES	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	SK	UK	ø
EATR																	
Nexus ratio																	
0	18.75	15. 50	8.30	18.75	21.71	8.42	9.38	19.76	11.25	18.70	19.08	18.75	12.36	16.22	19.64	14.25	15.68
10	16.68	14.49	7.44	17.29	19.96	7.87	8.77	18.37	10.28	16.76	16.31	17.19	11.14	14.96	18.37	13.37	14.33
20	14.61	13.47	6.57	15.83	18.21	7.32	8.16	17.07	9.30	14.81	13.65	15.63	9.93	13.73	17.09	12.50	12.99
30	12.53	12.46	5.71	14.36	16.46	6.78	7.55	15.78	8.33	12.87	11.11	14.07	8.72	12.52	15.81	11.62	11.67
40	10.46	11.44	4.85	12.90	14.71	6.23	6.94	14.50	7.35	10.92	8.69	12.51	7.52	11.35	14.54	10.74	10.35
50	8.39	10.43	3.98	11.44	12.96	5.68	6.33	13.22	6.38	8.98	6.39	10.95	6.33	10.20	13.26	9.86	9.05
60	6.32	9.42	3.12	9.98	11.21	5.14	5.72	11.94	5.40	7.03	4.20	9.39	5.15	9.08	11.98	8.99	7.75
70	4.25	8.40	2.26	8.51	9.46	4.59	5.11	10.67	4.43	5.09	2.13	7.83	3.98	8.00	10.70	8.11	6.47
76.92	2.81	7.70	1.66	7.50	8.25	4.21	4.69	9.79	3.75	3.74	0.77	6.75	3.17	7.26	9.82	7.50	5.59
80-100	2.81	7.70	1.66	7.50	8.25	4.21	4.69	9.79	3.75	3.74	0.77	6.75	3.17	7.26	9.82	7.50	5.59
Minimum share of own qualifying expenses																	
Target-EATR																	
5	66.37	.	38.23	94.02	95.51	62.48	71.81	.	64.10	70.44	56.78	88.14	61.23	94.34	.	.	80.88
7.5	54.30	.	9.27	76.92	.	16.81	30.82	.	38.46	57.59	46.70	72.12	40.43	73.32	.	76.92	61.94
10	42.23	54.26	.	59.83	66.93	.	.	75.20	12.82	44.74	36.61	56.09	19.64	52.30	75.52	48.43	43.00
15	18.10	4.93	.	25.64	38.35	.	.	36.68	.	19.03	16.45	24.04	.	10.26	36.35	.	5.12

Notes: Scenario of an equity-financed investment in a self-developed patent. "." indicates that this EATR cannot be reached either because the regular EATR is already below the target-EATR or because the maximum IP box benefit is not sufficient to reach the target-EATR.
Source: own calculation

Appendix 24: Effective tax burden for a debt-financed investment in a (self-developed) patent as of 2021 (%)

	BE	CH	CY	ES	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	SK	UK	ø
CoC																	
No qualifying expenses																	
Acquired patent	3.06	4.04	4.54	3.92	3.85	4.68	4.54	3.68	4.12	3.92	3.25	3.92	4.24	3.50	4.14	4.24	3.98
Self-development (regular tax system)	3.26[a]	3.66	4.13	3.26	3.11	4.37	4.13	3.33	3.96	3.26	2.56	3.26	3.68	2.81	3.54	3.68	3.50
Full self-development																	
Self-development (IP box)	4.74	4.38	4.92	4.30	4.28	4.85	4.56	4.16	4.65	4.65	4.88	4.37	4.65	3.90	4.62	4.30	4.51
EATR																	
No qualifying expenses																	
Acquired patent	11.48	10.94	7.34	14.68	17.61	5.29	7.34	16.10	7.51	14.65	20.56	14.68	11.16	18.50	12.33	11.16	12.58
Self-development (regular tax system)	12.22	9.41	5.57	12.22	14.99	3.90	5.57	14.83	6.81	12.19	18.33	12.22	8.89	16.12	9.98	8.89	10.76
Full self-development																	
Self-development (IP box)	1.56	4.06	1.47	4.37	5.05	2.64	2.65	6.85	2.10	2.09	0.71	3.90	2.10	7.19	6.17	4.37	4.38

Notes: [a]In BE a general investment credit applies to patent acquisitions, which allows for an increased depreciation above 100% over the useful life. The omission of this credit in the scenario of self-development drives the increase in the CoC in the debt-financing scenario.
Source: own calculation

Appendix 25: Effective tax burden for a debt-financed investment in a (self-developed) patent under IP box regimes and R&D tax incentives as of 2021 (%)

	BE	CH	CY	ES	FR	HU	IE	IT	LT	LU	MT	NL	PL	PT	SK	UK	ø
CoC																	
IP box	4.74	4.38	4.92	4.30	4.28	4.85	4.56	4.16	4.65	4.65	4.88	4.37	4.65	3.90	4.62	4.30	4.51
R&D tax incentive	2.68	1.73	4.13	2.12	-4.68	2.42	-1.44	-1.33	-2.86	3.26	-4.33	3.26	-0.79	-5.81	-6.50	1.20	-0.43
both incentives	4.16	4.17	4.92	-1.16	-2.34	4.06	-0.75	0.08	2.55	4.65	-0.27	4.37	3.60	-3.52	-0.33	2.00	1.64
EATR																	
IP box	1.56	4.05	1.47	9.67	17.86	2.64	2.65	6.85	2.10	2.09	0.71	3.90	2.10	7.19	6.17	4.37	4.71
R&D tax incentive	4.19	1.65	5.57	-5.46	-12.70	-4.98	-18.78	-1.98	-22.15	12.19	-4.06	12.22	-9.18	-13.39	-29.69	-1.12	-5.48
both incentives	-1.22	3.10	1.47	-20.20	-24.39	-1.10	-22.25	-10.71	-7.90	2.09	-24.57	3.90	-2.90	-24.09	-16.00	-5.98	-9.42

Notes: In CY, LU and NL the R&D scenario captures the baseline scenario without any R&D tax incentive. We do not consider the Dutch R&D incentive as it is applicable against payroll taxation instead of the corporate income tax.
Source: own calculation

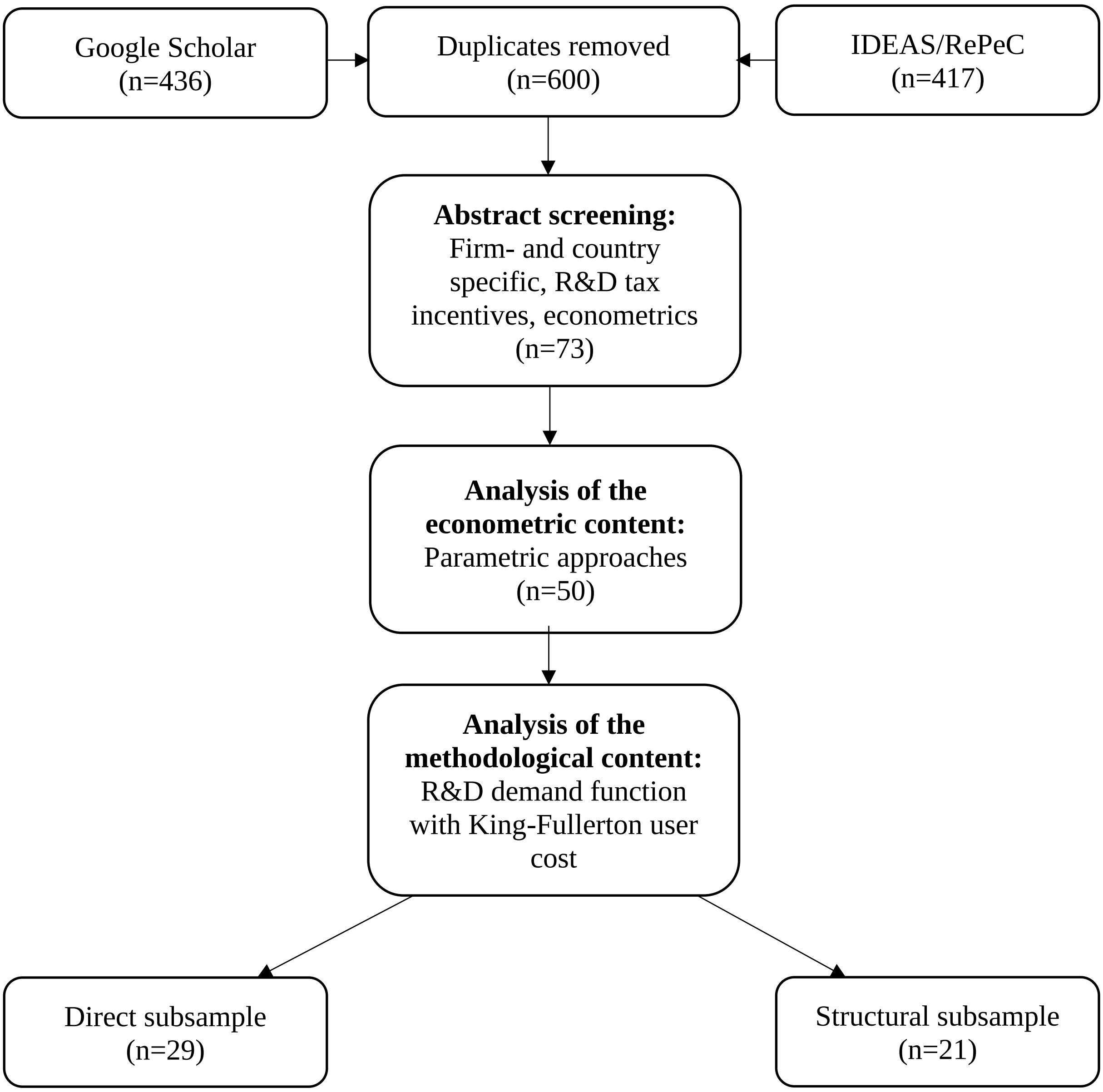
E. Appendix to Chapter 6

Appendix 26: JEL codes

	Category
H25	Business Taxes and Subsidies
H32	Firm
H42	Publicly Provided Goods
L13	Oligopoly and Other Imperfect Markets
O38	Government Policy
O32	Management of Technological Innovation and R&D
O31	Innovation and Intervention: Process and Incentives

Source: own composition

Appendix 27: Selection process and inclusion criteria



Source: own composition and illustration

Appendix 28: Structural approach sample across studies and sample periods

Study	Country	Period	Share best practice[a]	Average PCCtstat	Obs.
Agrawal et al. (2014)	Canada	2000-2007	1.00	-18.23	10
Baghana and Mohnen (2009)	Canada	1997-2003	0.75	-2.01	4
Crespi et al. (2016)	Argentina	1998-2004	0.33	-8.76	18
Domínguez (2006)	Spain	1991-1999	1.00	-2.54	4
Domínguez (2008)	Spain	1991-1999	1.00	-7.56	32
Fowkes et al. (2015)	UK	2003-2012	0.25	-1.96	4
Guceri and Liu (2019)	UK	2002-2011	0.00	-0.9	3
Hall (1993)	US	1980-1991	1.00	-9.41	5
Harris et al. (2009)	UK	1998-2003	1.00	-5.87	1
Jia and Ma (2017)	China	2009-2013	0.75	-1.43	16
Koga (2003)	Japan	1991-1998	1.00	-8.89	6
Labeaga et al. (2014)	Spain	2001-2008	0.33	-2.61	36
Lokshin and Mohnen (2007)	Netherlands	1996-2004	1.00	-2.71	5
Lokshin and Mohnen (2012)	Netherlands	1996-2004	0.67	-3.33	3
Mulkay and Mairesse (2008)[b]	France	1983-2002	1.00	5.71	1
Mulkay and Mairesse (2011)[b]	France	1981-2007	1.00	2.00	1
Mulkay and Mairesse (2011)[b]	France	1991-2003	1.00	-1.00	1
Mulkay and Mairesse (2011)[b]	France	2004-2007	1.00	0.81	4
Mulkay and Mairesse (2013)[b]	France	2000-2007	0.40	0.00	5
Mulkay and Mairesse (2018)	France	1999-2007	1.00	-3.20	2
Mulkay and Mairesse (2018)	France	2008-2013	1.00	-1.95	2
Rao (2010)	US	1981-1991	1.00	-8.99	2
Rao (2010)	US	1982, 1986-1990	0.70	-6.71	20
Rao (2013)	US	1986-1990	0.95	-4.11	22
Rao (2016)	US	1986-1990	0.92	-3.69	12
Thomson (2010)	Australia	1990-2005	0.50	-0.07	8

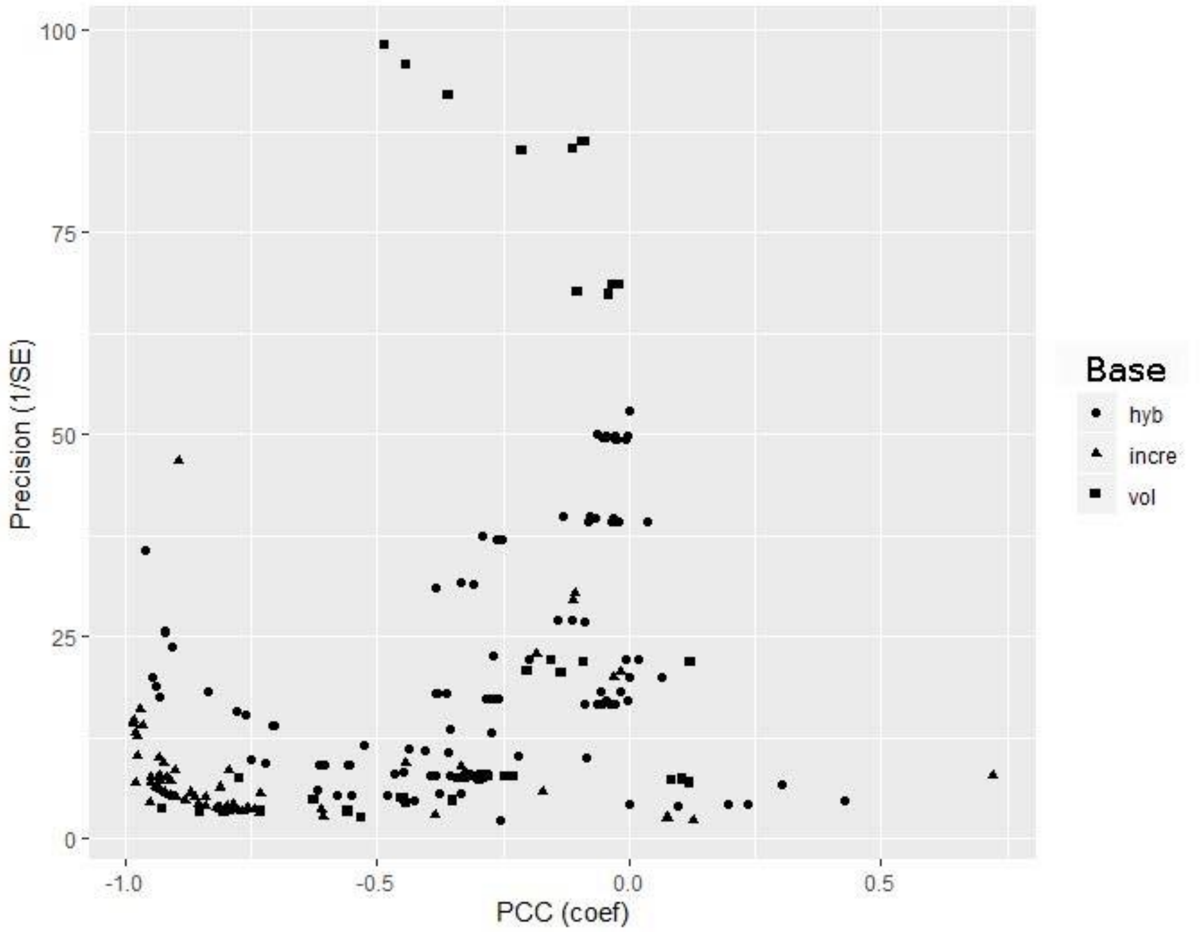
Notes: [a] The subsample of best practices comprises estimations relying on a synthetic user cost as instrumental variable or a GMM approach; [b] French estimates consider R&D adjustment costs in their estimations, exhibiting an increase in the long run.
Source: own composition and calculation

Appendix 29: Direct approach sample across studies and sample periods

Study	Country	Period	Share best practice[a]	Average PCCtstat	Obs.
Acheson and Malone (2020)	Ireland	2007-2014	1.00	0.60	8
Agrawal et al. (2020)	Canada	2000-2007	1.00	3.27	18
Aristei et al. (2015)	Spain	2007-2009	0.00	1.85	3
Berger (1993)	USA	1975-1989	0.00	3.40	2
Billings et al. (2001)	USA	1992-1998	0.00	1.04	2
Billings and Fried (1999)	USA	1994	0.00	2.25	1
Bozio et al. (2014)	France	2004-2010	0.50	2.87	6
Cantabene and Nascia (2014)	Italy	2007-2009	1.00	2.23	4
Calderón-Madrid (2010)	Mexico	2004-2007	0.00	2.46	6
Chen and Yang (2019)	China	2010-2012	0.00	8.67	5
Chen and Li (2018)	Taiwan	2006-2014	0.000	4.12[b]	3
Dechezleprêtre et al. (2020)	UK	2006-2011	1.00	1.92	1
Dechezleprêtre et al. (2020)	UK	2009	1.00	1.89	1
Dechezleprêtre et al. (2020)	UK	2009-2011	1.00	2.63	34
Dechezleprêtre et al. (2020)	UK	2010	1.00	2.50	1
Dechezleprêtre et al. (2020)	UK	2011	1.00	2.52	1
Dechezleprêtre et al. (2016)	UK	2006-2008, 2009-2011	1.00	1.42	5
Dechezleprêtre et al. (2016)	UK	2009	1.00	2.05	1
Dechezleprêtre et al. (2016)	UK	2009-2011	1.00	2.07	27
Dechezleprêtre et al. (2016)	UK	2010	1.00	2.69	1
Dechezleprêtre et al. (2016)	UK	2011	1.00	2.55	1
Dumont (2015)	Belgium	2003-2011	0.00	0.13	35
Dumont (2019)	Belgium	2003-2015	0.00	0.74	35
Guceri (2015)	UK	1999-2007, 2009-2013	1.00	2.02	5
Guceri (2015)	UK	2003-2006, 2008-2012	1.00	1.66	1
Guceri (2015)	UK	2003-2006, 2009-2012	1.00	1.41	1
Guceri (2015)	UK	2003-2007, 2009-2012	1.00	2.79	6
Guceri (2016)	UK	2003-2006, 2009-2012	1.00	1.14	10
Guceri (2016)	UK	2003-2006, 2010-2012	1.00	0.70	10
Guceri (2016)	UK	2003-2012	1.00	1.50	10
Guceri (2013)	UK	1998-2001, 2004-2006	1.00	1.50	10
Guceri (2013)	UK	1998-2006	1.00	1.70	10
Guceri and Liu (2015)	UK	2002-2006, 2009-2011	1.00	2.07	8
Guceri and Liu (2015)	UK	2002-2011	1.00	1.01	30
Guceri and Liu (2017)	UK	2002-2006, 2009-2011	1.00	2.53	8
Guceri and Liu (2017)	UK	2002-2011	1.00	2.24	30
Guceri and Liu (2019)	UK	2002-2006, 2009-2011	1.00	2.37	3
Guceri and Liu (2019)	UK	2002-2007, 2009-2011	1.00	2.43	7
Hægeland and Møen (2007)	Norway	1993-2005	0.89	6.22	35
Ho (2006)	US	1981-2013	0.08	1.43	24
Kasahara et al. (2014)	Japan	2001-2003	0.00	1.11	20
Kasahara et al. (2012)	Japan	2000-2003	0.00	1.01	12
Kasahara et al. (2012)	Japan	2003	0.00	1.29	36
Paff (2005)	US	1994-1999	1.00	2.34	6
Ravšelj and Aristovnik (2020)	Slovenia	2012-2016	0.00	3.76	2
Swenson (1992)	US	1975-1985	0.00	-1.10	3
Swenson (1992)	US	1975-1988	0.00	0.36	3
Thomson and Skali (2016)	Australia	2005-2011	0.00	21.55	3
Thomson and Skali (2016)	Australia	2011-2012	1.00	2.34	2
Thomson and Skali (2016)	Australia	2012	0.00	1.14	7
Yang et al. (2012)	Taiwan	2001-2005	0.00	2.22	6

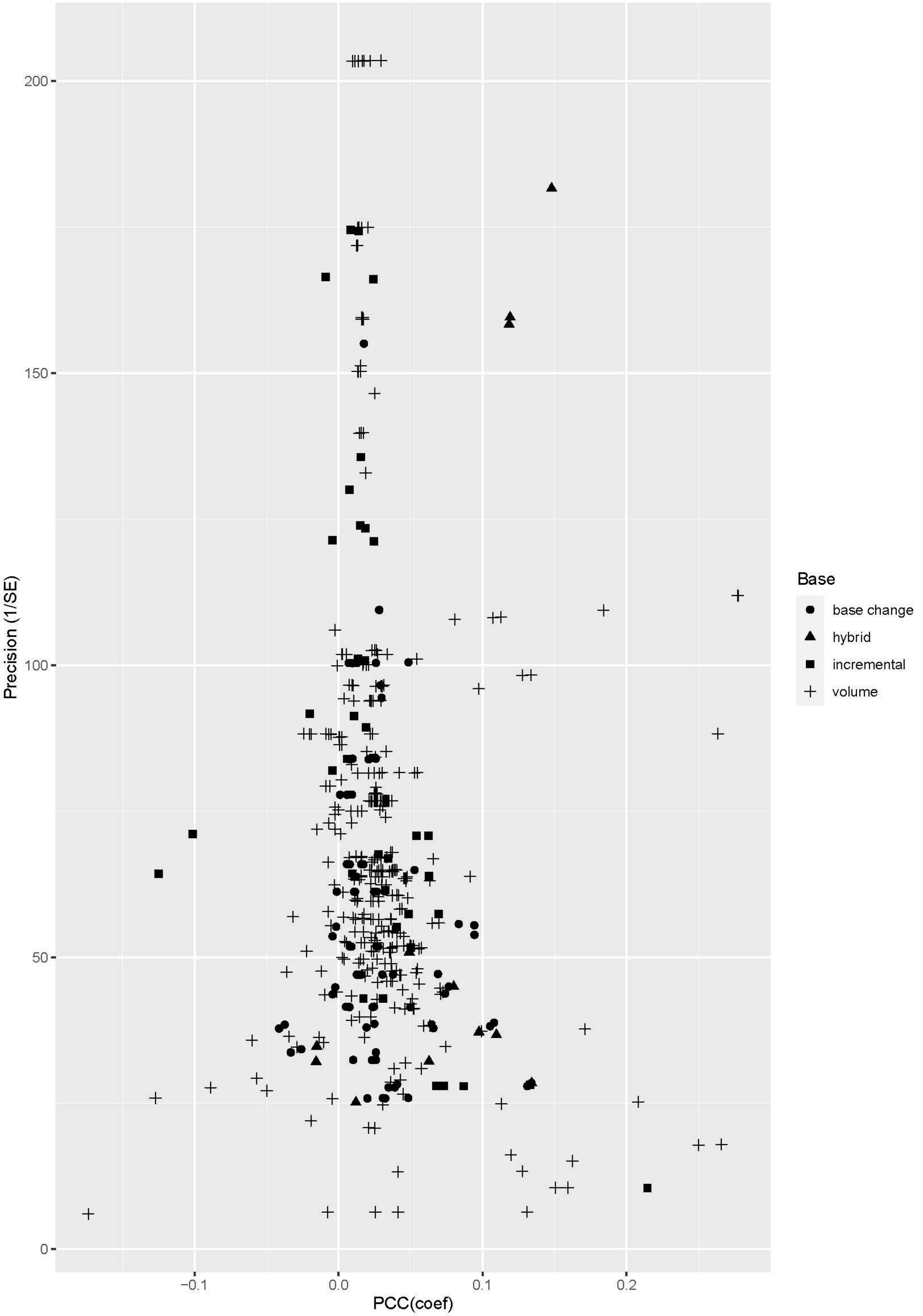
Notes: [a] The subsample of best practice comprises estimations relying on a DiD or an RDD design; [b] multiplied by -1 to account for the nature of the shock (abolition of tax incentives).
Source: own composition and calculation

Appendix 30: Funnel plot: PCC transformation of structural estimates



Source: own calculation and illustration

Appendix 31: Funnel plot: PCC transformation of direct estimates



Source: own calculation and illustration

Appendix 32: Structural approaches: subsample of best practices

	DeductionSE	IncrementalSE	HybridSE	VolumeSE	TargetedSE	Carry-forwardSE	ApprovalSE	CapSE	GMM	Spainpost	Spain
DeductionSE											
IncrementalSE	-0.12										
HybridSE	-0.06	-0.32****									
VolumeSE	0.19*	-0.16*	-0.20*								
TargetedSE	0.10	-0.11	0.40****	0.78****							
CarryforwardSE	0.11	-0.22*	0.32****	0.81****	0.91****						
ApprovalSE	0.22*	-0.18*	0.21*	-0.05	0.04	-0.20*					
CapSE	-0.21*	0.17*	0.84****	-0.27*	0.35****	0.20*	0.08				
GMM	0.17*	-0.23*	0.28*	-0.01	0.16*	0.00	0.26*	0.17*			
Spainpost	-0.07	-0.14	0.77****	-0.09	0.37****	0.38****	-0.10	0.73****	0.00		
Spain	-0.15	-0.33****	0.70****	-0.20*	0.22*	0.23*	-0.23*	0.58****	0.35****	0.44****	
US	-0.16*	0.36****	-0.44****	-0.22*	-0.46****	-0.27*	-0.25*	-0.26*	-0.82****	-0.19*	-0.44****

Notes: ****, ***, **, * denote statistical significance at the 0.01 percent, 0.1 percent, 1 percent, and 5 percent level, respectively.
Source: own calculation.

Appendix 33: Direct approaches: subsample of best practices

	IncrementalSE	TargetedSE	VolumeSE	DeductionSE	CarryforwardSE	ApprovalSE	CapSE
IncrementalSE							
TargetedSE	-0.28****						
VolumeSE	0.74****	-0.41****					
DeductionSE	-0.08	-0.24****	0.16**				
CarryforwardSE	-0.48****	0.30****	0.54****	0.22****			
ApprovalSE	0.13*	-0.12*	0.13*	-0.24****	-0.40****		
CapSE	0.17**	0.50****	-0.14**	-0.06	0.13*	0.24****	
HybridSE	0.18**	-0.05	-0.19**	0.30****	0.18**	0.01	0.12*

Notes: ****, ***, **, * denote statistical significance at the 0.01 percent, 0.1 percent, 1 percent, and 5 percent level, respectively.
Source: own calculation and illustration

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