Discussion Paper No. 17-046

Tax Incentives for Research and Development and Their Use in Tax Planning

Olena Pfeiffer and Christoph Spengel

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 17-046

Tax Incentives for Research and Development and Their Use in Tax Planning

Olena Pfeiffer and Christoph Spengel

Tax Incentives for Research and Development and Their Use in Tax Planning

Olena Pfeiffer*

(ZEW Mannheim)

and

Christoph Spengel

(University of Mannheim)

This study provides a comprehensive analysis of various aspects of R&D tax incentives. It explains the economic justification behind the state support of research and development and summarizes its main types. In addition, it gives an overview of the existing R&D tax incentives in Europe and provides a thorough review of the empirical literature on the outcomes of fiscal incentives. Furthermore, the Devereux and Griffith model is used to determine the effective tax burden of multinational firms that reside in countries which implement R&D tax support and countries which do not. The model is developed further following Spengel and Elschner (2010) and Evers et al. (2015) to reflect a potential use of R&D tax incentives by multinational firms for tax planning. The hypothesis developed in the model is tested in an empirical estimation, where we employ the OECD data on international co-operation in patents. According to our main findings, there are at least two reasons why input-oriented R&D tax incentives, such as tax credits and tax super-deductions, constitute a more suitable instrument for fostering research and development than the output-oriented incentives, such as IP Boxes. First, there is robust evidence found in the empirical literature which shows the positive effect introducing input-oriented tax incentives has on a firm's innovative activity, whereas studies on output-oriented tax incentives are not able to support this argument. Secondly, according to our theoretical and empirical analyses, output-oriented R&D tax incentives may be used by multinationals for tax planning as opposed to their intended use of fostering research and development.

Keywords: research and development; R&D; tax planning; corporate taxation

JEL-Classification: H25, F23, H26, H3

---

* Corresponding author: Centre for European Economic Research (ZEW Mannheim); e-mail: olena.pfeiffer@zew.de; phone: +49 (0) 621-1235-141; P.O. Box: ZEW Mannheim, L7, 1, 68161 Mannheim, Germany.

This paper contributes to MaTax – The Mannheim ScienceCampus for Taxation

1 Introduction

State support of research and development (R&D) is not only economically justified in numerous theoretical and empirical studies but is also enforced in many countries around the world. Fiscal incentives constitute one of the key instruments of state support of R&D, as they are easier to implement and are less complex to monitor than, for example, direct R&D grants or subsidies. There are various types of fiscal incentives for research and development, some of which focus on supporting the development or input phase of a research process, whereas others concentrate on the income-generating output phase. The first group of R&D tax incentives includes tax credits and tax super-deductions, which are more widely distributed on an international level than the second category. However, in recent years output-oriented fiscal incentives, which include intellectual property (IP) Boxes, seem to have been gaining popularity, especially in Europe. Fourteen European countries currently have IP Box regimes and several others are considering their introduction.

Even though R&D tax incentives have already been analyzed in the previous literature, the main aim of this study is to carry out a comprehensive analysis of various aspects of R&D tax incentives, including not only well-researched issues but also topics which have been studied to a lesser extent. The focus of this study is on the potential use of R&D tax incentives for tax planning by multinational enterprises (MNEs). We distinguish between input- und output-oriented fostering of R&D and concentrate on those incentives that apply to large companies, as opposed to the incentives which are available to small and medium enterprises. The study also focuses on those incentives that are available in member states of the European Union (EU) and the European Free Trade Area (EFTA) which includes Iceland, Liechtenstein, Norway, and Switzerland.

The methodology of our analysis is diverse. First, we carry out a thorough review of the existing R&D tax incentives and find that Germany, Estonia, and Sweden are currently the only countries in Europe that do not offer any R&D tax incentives. Secondly, we examine the empirical literature on the outcomes of an implementation of R&D tax incentives. According to the literature review, numerous studies find that input-oriented tax incentives boost firms' innovation and performance. However, there is no such strong evidence on the role of output-oriented fiscal incentives in supporting real R&D activity. Thirdly, we use the Devereux and Griffith (1999, 2003) approach to compute the effective average tax burden in the EU and EFTA member states in 2012. Furthermore, we follow the conceptual framework of Spengel and

Elschner (2010) and Evers et al. (2015) to incorporate various types of R&D tax incentives in the Devereux and Griffith model. In addition to a domestic investment scenario, a cross-border investment is introduced into the model in order to show that R&D tax incentives may be used by multinationals for tax planning. Finally, we test this hypothesis in an empirical analysis by employing data on international collaboration in patents provided by the Organization for Economic Co-Operation and Development (OECD). This data contains information on patents that have been developed in one country and relocated to another one afterwards. According to our main findings, a negative correlation exists between taxation and the probability of countries entering into a co-operation in patent development. In addition, the probability and the intensity of collaboration in patents increases with a growing generosity of R&D tax incentives, which further supports our hypothesis. Hence, we conclude that input-oriented R&D tax incentives, such as tax credits and tax super-deductions, constitute a more suitable instrument for fostering research and development than output-oriented fiscal incentives, such as IP Boxes.

The study is organized as follows: section 2 presents the economic justification behind the state support of R&D and introduces the main types of R&D tax incentives. In addition, an overview of the existing incentives in the EU and EFTA member states in 2012 is given. Section 3 includes a review of empirical literature on the outcomes of an implementation of R&D tax incentives. Section 4 explains the standard case of the Devereux and Griffith model and presents its extension to include input- and output-oriented R&D tax incentives. Moreover, this section further develops the model to demonstrate the role of fiscal incentives in tax planning strategies of multinational firms. Section 5 presents our empirical analysis and discusses the key results, with the final section summarizing the main findings of our study and drawing several conclusions.

2 State Support of Research and Development

2.1 Economic Justification

According to the OECD (2002), research and development can be defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge […] and the use of this stock of knowledge to devise new applications."[1] There is an established view among policy makers and in academia that R&D leads to technological development, which in turn

[1] See OECD (2002), p. 30.

stimulates economic growth. Solow (1956) was among the first economists to develop a theoretical model that illustrates this idea. According to the author, technological progress increases a country's productivity and proves to be more effective in fostering economic growth than other factors of production, such as labor and capital. Since technological progress plays an important role in the economic development of a country, it is natural that governments have an interest in supporting research and development, as Arginelli (2015) notes.

The two major economic justifications for the state support of research and development are positive spillovers from R&D and an existence of asymmetric information. According to Mankiw and Taylor (2014), positive spillovers from R&D occur because companies may use outcomes of research and development without there being rivalry or exclusion. As an example, different firms may apply research findings in product development at the same time while avoiding the possibility of limiting each other's research. This results in a lack of rivalry occurring between the firms. All companies can typically take advantage of the knowledge acquired through R&D, which implies that there is no exclusion. Spengel and Wiegard (2011) argue that positive spillovers from R&D may occur even in the case of a patent protecting the research outcomes, because firms could imitate new products or production processes of their competitors even if they are patented.

Furthermore, companies may also benefit from hiring experienced employees who have previously worked for their competitors and have gained the required knowledge needed to imitate these products. In addition, even if the outcomes of research and development are not successful and no new inventions result from a research project, there is still a positive spillover effect for the industry. Namely, other firms can learn from unsuccessful attempts made by their competitors and either avoid repeating the same mistake in the future or plan their research differently from the very beginning. Hence, the social benefits from research and development might exceed the private returns. Hansson and Brokelind (2014) investigate the consequences of introducing R&D incentives in the European Union, placing an emphasis on Sweden. The authors argue that the EU should subsidize only R&D projects which have a potential to yield higher social benefits than private returns. According to Hansson and Brokelind (2014), firms are likely to undertake projects with high private return regardless of any support measures which are available.

The second justification for the state support of research and development is the existence of asymmetric information. According to Spengel and Wiegard (2011), the problem of asymmetric information is typical for credit markets where some economic agents have better access to information than the others. This is particularly true in the case of financing R&D, because investments in this area are often deemed to be high-risk and creditors do not have the sufficient information to decide whether or not they should finance them. This results in adverse selection, whereby it is only low-risk R&D projects that receive financing with the other projects being overlooked, even if their potential returns are high. In addition, Arginelli (2015) argues that the issue of asymmetric information in capital markets may be selective and only give a disadvantage to certain types of firms. For example, small companies might have to pay higher interest rates and may have narrower access to the capital market compared to large firms. State support of research and development cannot prevent the problem of asymmetric information, but it can reduce the need for external means in R&D financing.

2.2 Types of R&D Support

State support of research and development can take various forms and target different phases of an R&D process. For example, governments may support R&D either directly or indirectly and in the case of direct measures, these may be taken in the form of subsidies, allowances, and grants. Even though this type of R&D support has a direct influence on the liquidity of an investing firm, its application process is often bureaucratic, complex, and lengthy. In addition, Cunningham et al. (2013) note that the provision of direct R&D funding might be quite subjective and based on certain characteristics of a firm, such as its age or experience in a certain field of research. Indirect measures include fiscal incentives for research and development and it is this type of state support of R&D which this study will focus upon.

Furthermore, R&D support can be classified according to the phase of the research process to which it applies. According to Arginelli (2015), a research project typically has two major stages. During a so-called input phase, a firm plans and conducts the research and it is during this stage where the majority of costs related to an R&D process arise. After an intangible asset has been created, the output phase begins which includes managing the profits that an intangible generates or dealing with the losses that have occurred in the case of an unsuccessful investment. This study analyzes both input- and output-oriented R&D tax incentives.

2.2.1 Input-Oriented R&D Tax Incentives

R&D tax incentives that apply to the first phase of the research process aim to alleviate the financial burden of a company as R&D expenses occur but income is yet to be generated or is completely uncertain. There are different approaches to support companies in this phase of investment. Some of the support measures aim to reduce a firm's tax liability, while others target its tax base. The first category includes an R&D tax credit, which can be defined as a direct offset against the amount of a company's tax liability.[2] The second group comprises a tax super-deduction and an accelerated depreciation of assets used in research and development. The OECD (2014) defines a tax super-deduction as a tax measure that reduces a firm's tax base by allowing for an inflation of the R&D expenditure base.[3] An accelerated depreciation scheme is defined as a tax incentive that permits fixed assets used in R&D to be depreciated at higher rates than usual in the first years of their useful life.[4] As the OECD (2014) notes, this type of R&D support decreases the overall taxable income of a company and provides it with some additional liquidity in certain periods of an R&D process. However, the payment of taxes in this case is not completely repealed but rather postponed. According to Spengel and Wiegard (2011), the attractiveness of R&D tax incentives that target a company's tax base rises as a country's statutory corporate income tax (CIT) rate increases. This is due to a larger effect of the fiscal incentives on the tax base when a tax rate is higher.

These R&D tax incentives can be further divided according to their attributes. Arginelli (2015) gives a detailed overview of input-oriented R&D tax incentives with respect to their targeting dimensions, such as the type of income which they support as well as intangible assets, business sectors, and firm sizes they apply to. For example, some countries offer incremental tax credits and tax deductions, which depend on the volumes of R&D expenses in previous periods and therefore should intensify an increase in a firm's spending on research and development. Moreover, R&D tax incentives may differ according to the type of expenses they support. For example, some of them target current expenses such as labor costs or maintenance expenditure, while others support capital expenses such as costs associated with the construction of a laboratory or a building. As a concluding point, it should be taken into account that the incentives may vary based on their treatment of losses that result from an R&D process. Some

---

[2] See OECD (2016a).
[3] See OECD (2014), p. 51-52.
[4] See OECD (2014), p. 52.

countries allow unused tax incentives to be carried forward, while other countries offer a refund in the case of losses, which is equal to a cash grant.

2.2.2 Output-Oriented R&D Tax Incentives

In addition to the input-oriented R&D incentives, there are also tax incentives that target the second stage of research and development. In particular, they aim to provide a favorable tax treatment for the income generated from intangible assets. IP Boxes serve as a prominent example of this type of R&D incentives. Atkinson and Andes (2011) define an IP Box as a tax incentive that allows corporate income from the sale or licensing of intangible assets to be taxed at a lower rate than other types of income.[5]

In their overview of the existing IP Boxes, Evers et al. (2015) demonstrate a great variety of these regimes. For instance, IP Boxes differ according to the type of income, intangible assets, and R&D expenses that they cover. Some regimes allow a deduction of current R&D expenditure from the tax base of a reduced tax rate, which is known as a net approach. By contrast, other IP Boxes permit the deduction from the tax base of a standard statutory tax rate, defined as a gross approach. The latter method is to the benefit of the investing companies, since here the profits generated by an intangible are taxed at the reduced tax rate, although the expenses associated with its development are deducted at the higher statutory tax rate. In addition, IP Boxes may differ in their treatment of the R&D expenditure that occurred in the past. For example, the past expenses on research and development may be ignored (a no recapture approach) or it may be necessary to reconsider them (a recapture approach). In the case of a recapture approach, it may either be required to deduct the past expenses at the reduced IP Box tax rate (a threshold method) or to capitalize them (a capitalization method).[6]

Furthermore, some IP Boxes only apply to intangible assets that have been developed within a country's borders, whereas others support IP acquired from abroad as well. In the case of the latter, an IP Box does not have to foster domestic research and development but might rather be used by multinational enterprises for tax planning. The OECD has attempted to fix this problem by imposing the Nexus Approach in 2015.[7] According to this regulation, all current and new IP Boxes should facilitate the taxation of profits from the transfer or use of intangible

[5] Atkinson and Andes (2011), p. 3.
[6] See Evers et al. (2015) for more information.
[7] See OECD (2015).

assets in the place of their creation. However, the enforcement of this requirement still depends on the willingness of individual countries to co-operate.

Spengel (2016) identifies that another issue related to the lawfulness of IP Boxes is their potentially selective treatment of certain companies or industries. The author argues that IP Boxes give an advantage to multinational enterprises compared to the purely domestic firms. A multinational might develop an intangible in a high-tax country and afterwards strategically relocate it to a subsidiary in a country with an IP Box, whereas a domestic firm does not have this opportunity. Moreover, IP Boxes distort competition by giving an unfair advantage to companies that operate within certain industries. As an example, firms within some industries may develop an intangible asset and then license it to other related and non-related companies, whereby the resulting license fees will typically be eligible for beneficial tax treatment under an IP Box regime. By contrast, companies within other industries may use their intangible assets only themselves and are not able to license them to other parties. As a result, forms in the second category are not able to benefit from using an IP Box in comparison to their counterparts in the first category. Therefore, Spengel (2016) concludes that the selective treatment of IP Boxes does not comply with the state aid principles of the European Union.

2.3 An Overview of R&D Tax Incentives in Europe

This section gives an overview of the current input- and output-oriented R&D tax incentives in the 28 member states of the European Union and four countries that are non-EU members but belong to the European Free Trade Area (Iceland, Liechtenstein, Norway, and Switzerland).[8] Figure 1 presents the distribution of the R&D tax incentives across these countries in 2012 and what is evident from this figure is that the majority of European countries offer either input- or output-oriented fiscal incentives. It is worth noting that some countries have even implemented both types of R&D tax incentives. For example, France offers both a generous tax credit on R&D expenditure and an IP Box. By contrast, Estonia, Germany, Greece, Latvia, Slovakia, and Sweden were the only countries in Europe that did not offer any kinds of R&D tax incentives in 2012. However, Greece, Latvia, and Slovakia have introduced super-deductions for R&D expenses in the years that followed, which resulted in Estonia, Germany, and Sweden currently remaining the only countries in Europe without fiscal incentives for research and development.

[8] In what follows, we refer to the EU and EFTA members as Europe.

2.3.1 Input-Oriented R&D Tax Incentives

Table 1 gives an overview of the existing input-oriented R&D tax incentives in Europe. It focuses on the incentives that are available for large corporations; however, many countries have special R&D tax incentives for small and medium enterprises as well. In addition, it is worth noting that Table 1 summarizes fiscal incentives available for internal R&D spending, since in our further analysis we assume that a company conducts research itself and does not outsource it to other parties (which would result in external R&D spending).

According to Table 1, only a few European countries such as Cyprus, Estonia, Germany, Greece, Liechtenstein, Slovakia, and Sweden do not offer any input-oriented incentives for R&D. In addition to input-oriented incentives, most countries do not require an immediate capitalization of self-developed intangible assets for tax purposes. However, a few countries such as Cyprus, Norway, and Slovakia enforce this requirement and thereby create a liquidity disadvantage for firms that carry out research and development.

Figure 1. Existing Input- and Output-Oriented R&D Tax Incentives in Europe, 2012

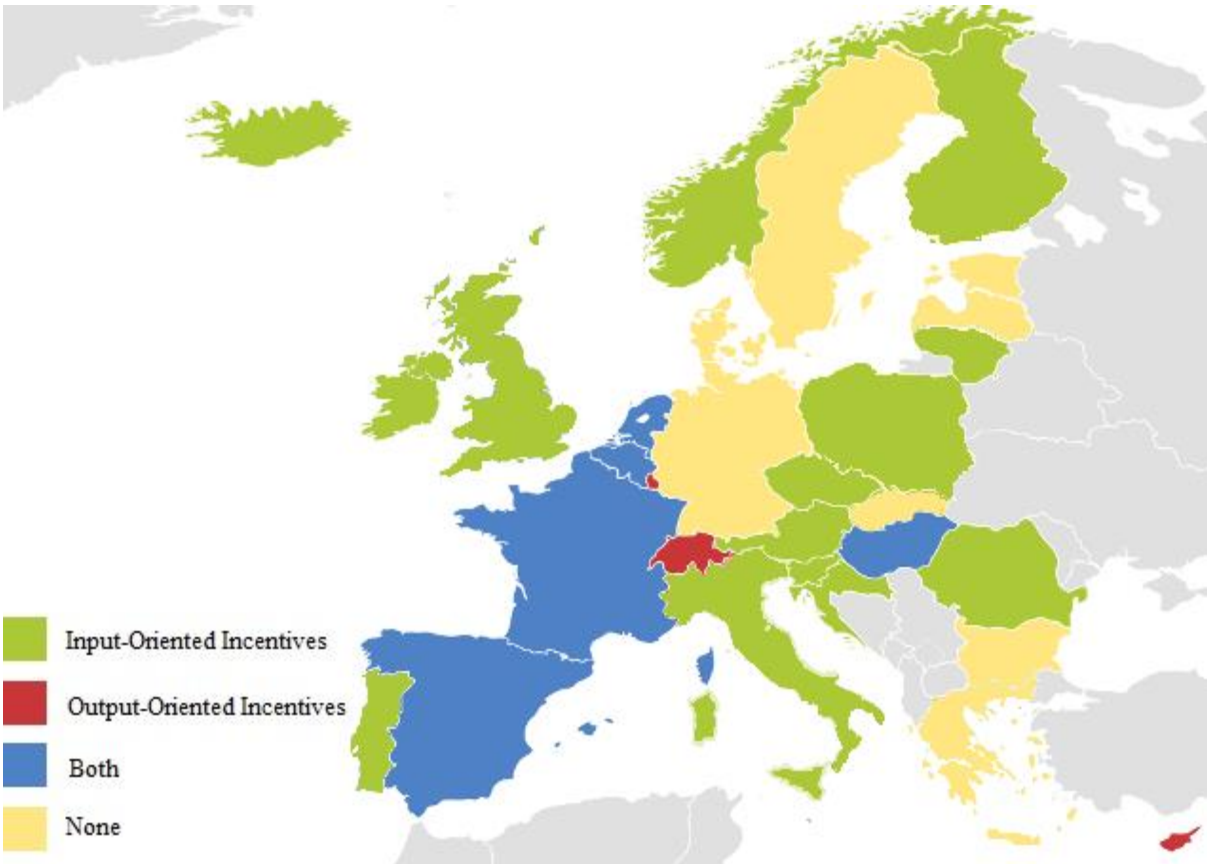


Table 1. An Overview of Input-Oriented R&D Tax Incentives in Europe, 2012

	Tax Credit, %	Super-Deduction, %	Qualifying Expenses		Accelerated Depreciation	Losses	
			Current	Capital		Carry Forward	Refund
Austria	10[1]	-	x	x	-	-	x
Belgium	13.5[2]	13.5[2]	x	-	-	-	-
Bulgaria	-	-	-	-	x[16]	-	-
Croatia	-	100[13]	x	x	-	-	-
Cyprus	-	-	-	-	-	-	-
Czech Republic	-	100[14]	x	x	-	x	-
Denmark	-[3]	-	-	-	x	-	x
Estonia	-	-	-	-	-	-	-
Finland	-	-	-	-	x	-	-
France	30[4]	-	x	x	x[17]	x	x[22]
Germany	-	-	-	-	-	-	-
Greece	-	-	-	-	-	-	-
Hungary	-[5]	100	x	x	-	-	-
Iceland	20[6]	-	x	x	-	-	-
Ireland	25	-	x	x	x[16]	x	-
Italy	-[7]	-	-	-	x[16]	x	-
Latvia	-	-	-	-	-	-	-
Liechtenstein	-	-	-	-	-	-	-
Lithuania	-	200	x	x	x	x	-
Luxembourg	-	-	-	-	x[18]	-	-
Malta	15[8]	50[8]	x	x	-	x	-
Netherlands	-	40	x	x	-	x	-
Norway	18[9]	-	x	x	-	-	x
Poland	-	-[15]	-	-	x[19]	-	-
Portugal	32.5[10]	-	x	x	-	x	-
Romania	-	20	x	x	x[20]	x	-
Slovakia	-	-	-	-	-	-	-
Slovenia	-	40	x	x	-	x	-
Spain	25[11]	-	x	x	x[16]	x	-
Sweden	-	-	-	-	-	-	-
Switzerland	-	-	-	-	x[21]	-	-
UK	-[12]	30	x	x	x[16]	x	x

Notes: [1]Approval of the Austrian Research Promotion Agency is required. [2]These R&D incentives are available only for green investments and are mutually exclusive. [3]Tax credit is capped and is available only for firms encountering R&D-related losses. [4]30% up to 100 million EUR, 5% above. The rate is increased to 40% in the first year and to 35% in the second year for companies that benefit from the tax credit for the first time or did not benefit from it during the five years before they request the credit. [5]A tax credit of up to 80% for investments in underdeveloped regions and free entrepreneurial zones is available. [6]An approval of the Icelandic Centre for Research is required; minimum 1 million ISK, maximum 100 million ISK per project and firm. [7]There is no general tax credit, although there is a 10%-credit on R&D expenses that do not exceed 50 million EUR. [8]Not allowed if an IP box applies. [9]The credit is generally given to small and medium companies but may also apply to other firms upon an approval of the Research Council of Norway. [10]An additional incremental credit of 50% applies if expenses exceed the average R&D expenditure of the previous two fiscal years. [11]If expenses exceed an average amount of the previous two years, a rate of 25% applies to the average amount and a rate of 42% applies to the exceeding amount. [12]A taxable 11%-tax credit is available in certain cases but not for the expenses on patents. [13]This amount ranges between 100% and 150% depending on a type of research. [14]The rate increases to 110% for incremental R&D expenses. [15]Application is possible if certain conditions are fulfilled. [16]An immediate write-off. [17]Degressive instead of straight-line depreciation is possible if a resulting asset stays in the enterprise for at least 3 years. [18]Accelerated depreciation for machinery and equipment; buildings are excluded. [19]Accelerated depreciation is not limited to assets used in research and development. [20]A write-off of 50% in the first year is available for machinery and equipment if the resulting IP stays in Romania. [21]Varies on the cantonal level, with most cantons offering an immediate or accelerated depreciation for machinery, buildings, and intangible assets. These tax incentives are not limited to the assets used in R&D. [22]A unutilized tax credit may be carried forward for three years, afterwards a refund is available.

Table 1 shows that most European countries offer either a tax credit or a tax super-deduction for R&D expenditure. In line with Spengel and Elschner (2010), we distinguish between current and capital expenditure on research and development and observe that the majority of countries in Table 1 offer tax incentives for both current and capital expenses. Furthermore, almost half of the countries under analysis allow for an accelerated depreciation of machinery, buildings, intangibles, and other types of assets used in research and development. As discussed in section 2.2.1, accelerated depreciation gives firms a liquidity advantage in the first years of research and development. In the case of losses, most countries permit their tax incentives to be carried forward and only a few of them offer a refund. A few countries offer both options for the treatment of losses.

2.3.2 Output-Oriented R&D Tax Incentives

Table 2 provides an overview of the output-oriented R&D tax incentives represented by IP Boxes. Similarly to the input-oriented instruments, the scope of Table 2 includes countries of the European Union and the European Free Trade Area in 2012. The output-oriented R&D incentives have become rather popular in recent years, as shown by the fact that ten European countries offered them in the year 2012. Four more countries have introduced IP Boxes in the years following on from 2012 (Ireland in 2016, Italy in 2015, Portugal in 2014, and the United Kingdom in 2013) and several others are considering the possibility of doing so.

Table 2. An Overview of Output-Oriented R&D Tax Incentives in Europe, 2012

	Date of Implementation	IP Box Tax Rate, %	Statutory Tax Rate, %	Type of Eligible IP		Treatment of Expenses	
				Acquired	Existing	Current	Occurred in the Past
Austria	-	-	25	-	-	-	-
Belgium	2007	6.8	33.9	N	N	Gross	No recapture
Bulgaria	-	-	10	-	-	-	-
Croatia	-	-	20	-	-	-	-
Cyprus	2012	2.5	10	Y	Y	Net	Recapture (Capitalization)
Czech Republic	-	-	19	-	-	-	-
Denmark	-	-	25	-	-	-	-
Estonia	-	-	21	-	-	-	-
Finland	-	-	24.5	-	-	-	-
France	2000	15.5	34.4	Y[3]	Y	Net	No recapture
Germany	-	-	29.8	-	-	-	-
Greece	-	-	20	-	-	-	-
Hungary	2003	9.5	19	Y	Y	Gross	No recapture
Iceland	-	-	20	-	-	-	-
Ireland[1]	-	-	12.5	-	-	-	-
Italy[1]	-	-	31.4	-	-	-	-
Latvia	-	-	15	-	-	-	-
Liechtenstein	2011	2.5	12.5	Y	N	Net	Recapture (Threshold)
Lithuania	-	-	15	-	-	-	-
Luxembourg	2008	5.9	28.8	Y[3]	Y	Net	Recapture (Capitalization)
Malta	2010	0	35	Y	N	Not deductible	Not if costs were deducted
Netherlands	2007	5	25	N	N	Net	Recapture (Threshold)
Norway	-	-	28	-	-	-	-
Poland	-	-	19	-	-	-	-
Portugal[1]	-	-	25	-	-	-	-
Romania	-	-	16	-	-	-	-
Slovakia	-	-	19	-	-	-	-
Slovenia	-	-	18	-	-	-	-
Spain	2008	11.2	30	N	Y	Net	No recapture
Sweden	-	-	26.3	-	-	-	-
Switzerland[2]	2011	8.8	18	Y	Y	Net	No recapture
UK[1]	-	-	24	-	-	-	-

Notes: [1]Ireland has introduced an IP Box in 2016, Italy in 2015, Portugal in 2014, and the UK in 2013. [2]Only in Nidwalden. [3]In France and Luxembourg acquired IP is admitted to the IP Box only under certain circumstances. The statutory tax rates correspond to corporate income tax rates including any surcharges, local taxes, or other taxes. Abbreviations: Y: yes, N: no.

According to Table 2, all IP Boxes significantly decrease taxation of profits generated by intangible assets. For example, in Malta the standard corporate income tax rate reaches 35%, while the reduced IP Box tax rate equals 0%. As shown in Table 2 and as discussed in section 2.2.2, before the implementation of the OECD Nexus Approach in 2015, the majority of IP Boxes were open for acquired IP as well. Furthermore, according to Table 2, some IP Boxes enable a preferential tax treatment of the existing intangibles in addition to the newly created ones. Belgium and Hungary are the only two countries that permit a gross approach in the treatment of current R&D expenses. As described in section 2.2.2, this method is beneficial from a company's point of view, since it allows firms to deduct R&D expenditure at a regular tax rate.

As for the research expenses that occurred in the past, around half of the existing IP Boxes do not require a recapture of previous R&D expenses, as Table 2 shows. By contrast, in Liechtenstein and the Netherlands they have to be recaptured in accordance with the threshold approach and in Cyprus and Luxembourg they have to be reconsidered following the capitalization method. In Malta, R&D expenses are not allowed to be deducted if an IP Box regime applies. In this case, a company has to decide whether to deduct its R&D expenditure and benefit from the input-oriented R&D tax incentives or to apply for an IP Box and achieve a full tax exemption of profits generated by intangible assets.

3 A Review of Empirical Literature on the Effectiveness of R&D Tax Incentives

3.1 The Impact of Input-Oriented R&D Tax Incentives

Numerous empirical papers have evaluated the effectiveness of input-oriented R&D tax incentives. Table 3 presents an overview of studies conducted in this field of research between 2002 and 2016. These studies make use of different data samples and econometric techniques and nevertheless all of them identify a positive correlation between input-oriented R&D tax incentives and the private sector's innovative activity. Panel A of Table 3 shows an overview of papers that evaluate an influence of the user costs of R&D or the B-Index on research and development, whereas Panel B focuses on literature that estimates the outcomes of reforms that have introduced input-oriented tax incentives.

3.1.1 The Impact of User Costs and B-Index

In studies shown in Panel A, the dependent variable – a private sector's innovative activity – is often proxied by firms' R&D expenditure or a number of new patent registrations. The main independent variable of interest in these papers is expressed either through the user costs of R&D or the B-Index. Jorgenson (1963) introduced the first of the two measures and Hall and Jorgenson (1967) further developed it. The user costs of R&D reflect the breakeven cost-benefit ratio of a marginal R&D investment after tax. Hence, this measure incorporates the reduction in a firm's corporate tax liability associated with each euro invested in R&D. Warda (2001) introduced the B-Index, which is an alternative measure of R&D costs.

$$B\_Index = \frac{1 - (A\,\tau)}{(1 - \tau)} \tag{1}$$

In equation 1, τ denotes statutory corporate income tax rate, whereas A represents a combined net present value of allowances and tax credits applied to R&D expenses. If an R&D investment is fully expensed in a fiscal year, both A and the B_Index are equal to one. Tax credits, tax deductions or any other kind of input-oriented tax incentives increase A, which results in the B_Index being smaller than one. Consequently, the lower the B-Index, the more attractive the tax system is for R&D investment and vice versa.

As shown in Panel A of Table 3, one of the first studies to estimate the effect of increasing user costs on innovation was Bloom et al. (2002). The authors use data from nine OECD countries over the years 1979-1997 and develop a measure for the user costs of R&D that contains depreciation allowances on R&D investments, net present value of R&D tax credits, and corporate income tax rates. In the empirical part of their analysis, Bloom et al. (2002) estimate a model in which the dependent variable equals the aggregate R&D expenses, while the independent variables include user costs of R&D, output, time- and country-specific fixed effects. In the baseline specification, the authors apply an instrumental variable approach and find a significant impact of fiscal incentives on R&D expenditure with a short-term elasticity of -0.1 and a long-term elasticity of -1.0. This implies that on average a 1% reduction in R&D user costs leads to a 0.1% increase in the R&D expenses in the short run and a 1% increase in the long run. A positive impact of decreasing user costs on R&D expenditure has been confirmed in numerous further studies using country- and firm-level data (see as examples: Baghana and Mohnen (2009), Wilson (2009), Lokshin and Mohnen (2012), Mulkay and Mairesse (2013), Thomson (2015)). Some authors have taken a step further by investigating the heterogeneity of this effect for different firm sizes and industry classes. For example, Baghana and Mohnen (2009) argue that the positive impact of decreasing R&D user costs on R&D spending is larger for small firms than for large companies.

Table 3. An Overview of Empirical Studies on the Effectiveness of Input-Oriented R&D Tax Incentives

Panel A. The Impact of User Costs and B-Index

Paper		Sample			
Authors	Year	Countries	Time Period	Empirical Model	Results
Bloom et al.	2002	9 OECD countries	1979-1977	OLS, IV	A positive effect of decreasing user costs on the level of R&D. The effect is larger in a long run than in a short run.
Falk	2006	21 OECD countries	1975-2002	GMM	A positive effect of decreasing B-Index on business R&D spending.
Baghana and Mohnen	2009	Canada, Quebec Manufacturing Firms	1997-2003	OLS, GMM	A positive effect of decreasing user costs on the level of R&D. The effect is larger in a long run than in a short run. In addition, the effect is larger for small firms than large companies.
Wilson	2009	the United States	1981-2004	OLS	A positive effect of decreasing user costs on the level of a state's R&D.
Corchuelo and Martínez-Ros	2010	Spain	2002	PSM, IV	A positive effect of decreasing B-Index on the level of R&D. Large firms in tech sectors benefit most from tax incentives for innovation.
Ernst and Spengel	2011	20 EU countries	1998-2007	OLS, Logit, Negative Binominal	A positive effect of decreasing B-Index on the probability to invest in R&D.
Lokshin and Mohnen	2012	Netherlands	1996-2004	IV	A positive effect of decreasing user costs on a firm's investment in R&D.
Mulkay and Mairesse	2013	France	2000-2007	GMM	A positive effect of decreasing user costs on a firm's investment in R&D.
Westmore	2013	19 OECD countries	1983-2008	mean-group estimator	A positive effect of decreasing B-Index on R&D expenditure and the number of new patent applications.

Ernst et al.	2014	members of the EPO	1995-2007	OLS, Diff-in-Diff	A positive effect of decreasing B-Index on the quality of patents.
Thomson	2015	26 OECD countries	1987-2006	OLS	A positive effect of decreasing user costs on R&D financed by the business sector.

A Meta-Study

Gaillard-Ladinska et al.	2015	16 articles, 82 effect estimates	Studies published between 1990 and 2014	A meta-regression analysis	A positive effect of decreasing user costs on a firm's stock of R&D capital and flow of R&D expenditure.

Notes: OLS stands for ordinary least squares, IV stands for instrumental variable, GMM denotes generalized method of moments, PSM stands for propensity score matching, Diff-in-Diff denotes a difference-in-difference estimation, EPO stands for the European Patent Office.

Panel B. Evaluation of a Treatment Effect

Paper		Sample		Empirical Model	Results
Authors	Year	Countries	Time Period		
Klassen et al.	2004	Canada, the United States	1991-1997	OLS	A positive effect of a tax credit reform on R&D spending. The impact is stronger in the US than in Canada.
Haegeland and Moen	2007	Norway	1993-2005	GLS, Diff-in-Diff	A positive effect of a tax credit reform on the R&D investment.
Lee	2011	Canada, Japan, Korea, Taiwan, China, India	1997	GMM, IV	A positive effect of a tax credit reform on the R&D investment. The effect varies across firms, industries, and country characteristics.
Yang et al.	2012	Taiwan	2001-2005	OLS, Logit, IV, GMM	A positive effect of a tax credit reform on a firm's R&D spending.
Bozio et al.	2014	France	2004-2010	Logit, Diff-in-Diff, PSM	A positive effect of a tax credit reform on the R&D investment but a possible lower impact on its innovation than could have been expected.
Kasahara et al.	2014	Japan	2000-2003	GMM	A positive effect of a tax credit reform on the level of R&D.
Kobayashi	2014	Japan	2009	Probit, PSM	A positive effect of a tax credit reform on the R&D spending of SMEs.
Guceri	2017	UK	2003-2012	Logit, Diff-in-Diff, PSM	A positive effect of a tax credit reform on the R&D spending.

A Meta-Study					
Castellacci and Lie	2015	34 articles, 404 effect estimates	Studies published between 1991 and 2013	A meta-regression analysis	A positive effect of a tax credit reform on the R&D investment. The effect is stronger for SMEs, firms in service sectors, and firms in low-tech sectors in countries with an incremental scheme.

Notes: OLS stands for ordinary least squares, GLS stands for generalized least squares, IV denotes instrumental variable, GMM means generalized method of moments, PSM stands for propensity score matching, Diff-in-Diff denotes a difference-in-difference estimation, SME stands for a small or medium enterprise.

Falk (2006), Corchuelo and Martínez-Ros (2010), Ernst and Spengel (2011), Westmore (2013), Ernst et al. (2014) find a positive impact of decreasing B-Index on a firm's R&D expenses and its probability to invest in research and development. Westmore (2013) argues that the declining B-Index has a positive effect not only on R&D expenditure but also on its innovation, measured as a number of new patent applications. Ernst et al. (2014) develop this idea further and state that the B-Index is negatively correlated with both the number of patent applications and also their quality. Finally, Gaillard-Ladinska et al. (2015) conduct a meta-study that analyzes 82 estimates from 16 empirical studies within this field of literature. The authors argue in favor of a positive effect of decreasing user costs on a firm's stock of R&D capital and its R&D expenditure. In addition, the effects found in the earlier and more recent studies are of approximately the same magnitude.

3.1.2 Evaluation of a Treatment Effect

Panel B of Table 3 presents an overview of empirical studies that evaluate effects of the reforms that have introduced input-oriented R&D tax incentives. These papers differ from those described in the previous section mainly through their identification strategy. Namely, they focus on a particular reform that changed (or introduced) fiscal incentives and compare the outcomes for treated and non-treated firms. However, many of the earlier studies in this area disregard the problem of a selection bias, according to which the recipients of R&D tax credits or super-deductions might systematically differ from the non-recipients. For this reason, recent studies such as Yang et al. (2012), Bozio et al. (2014), Kobayashi (2014), Guceri (2017) have estimated the effect of R&D tax incentives after meticulously correcting a possible selection bias using the propensity score matching (PSM) technique. This strategy helps to identify comparable companies and to classify and divide them into treatment and control groups.

A recent study by Guceri (2017) estimates the effect of R&D tax incentives in a quasi-experimental setting. The author exploits a recent reform in the UK, which increased a threshold for small or medium enterprises (SMEs) from 250 to 500 employees. This reform changed the composition of companies that were eligible for an R&D tax credit and therefore created a suitable design for an empirical investigation of the treatment effect. Using firm-level data from the UK over the period between 2003 and 2012, Guceri (2017) argues that tax incentives help to increase R&D spending at a company level. The author finds a user costs elasticity of -1.2, which implies that an introduction of an R&D tax incentive that decreases user costs by 1% leads to a 1.2% increase in R&D spending. Comparable results were found by other authors who conducted similar empirical analyses employing data on different countries and years of observation, such as Klassen et al. (2004), Haegeland and Moen (2007), Lee (2011), Yang et al. (2012), Kasahara et al. (2014), Bozio et al. (2014), and Kobayashi (2014). In addition, the effects found in the earlier and more recent studies are of around the same magnitude. Castellacci and Lie (2015) conduct a meta-study using 404 effect estimates from 34 empirical papers in this field of research. The authors are able to identify a positive effect of tax credit reforms on R&D investment. In addition, they argue that on average R&D tax credits have a stronger impact on SMEs, firms in service sectors, and firms in low-tech industries in countries with an incremental credit scheme.

3.2 The Impact of Output-Oriented R&D Tax Incentives

As discussed in section 2.3.2, several European countries have introduced IP Boxes to encourage innovation. An IP Box significantly reduces the taxation of income generated by qualifying intellectual property and in some cases it offers a beneficial treatment of R&D expenditure. Evers et al. (2015) give a detailed overview of the current IP Boxes in Europe and show the tax reductions they cause. Since in most cases IP Boxes are fairly new regulations, the empirical research on their effectiveness or outcomes is rather scarce. A few papers that attempt to evaluate the influence of IP Boxes on a firm's innovative activity are presented in Table 4.

Ernst et al. (2014) incorporate IP Boxes into their measurement of the taxation of royalty payments and argue that they contribute towards attracting patent ownership. Similar results are found by Griffith et al. (2014) who ex-ante estimate the impact of IP Boxes with data running until 2005 (most current IP Boxes have been introduced afterwards). The authors conclude that even though a greater number of patent applications are to be expected in countries with IP Boxes, these regimes likely lead to substantial revenue losses not only in countries where they have been introduced but also in the neighboring jurisdictions.

Table 4. An Overview of Empirical Studies on the Effectiveness of Output-Oriented R&D Tax Incentives

Paper		Sample			
Authors	Year	Countries	Time Period	Empirical Model	Results
Ernst et al.	2014	members of the EPO	1995-2007	OLS, Diff-in-Diff	IP Boxes contribute to attracting patent ownership.
Griffith et al.	2014	14 EU countries and the United States	1985–2005	Ex-ante analysis, Mixed Logit	IP Boxes are likely to have a positive effect on the number of patent registrations. They could also lead to a substantial reduction in tax revenues.
Alstadsæter et al.	2015	33 countries worldwide	2000-2011	Negative Binomial Logit	IP Boxes attract intangibles, especially high-quality patents. The effect is stronger for IP Boxes that are applicable to acquired IP. However, the existence of an IP Box incentivizes multinationals to shift the location of their patents without a corresponding increase in the number of inventors or a shift of research activities.
Dudar et al.	2015	61 countries worldwide	1990-2012	Poisson	IP Boxes that are applicable to acquired IP seem to attract royalty inflows. However, IP Boxes that are applicable only to self-developed IP do not appear to affect international royalty flows.
Bradley et al.	2015	71 countries worldwide	1990-2012	OLS	IP Boxes lead to an increased patenting activity in a country of their implementation.

Notes: OLS stands for ordinary least squares, Diff-in-Diff denotes a difference-in-difference estimation, and EPO stands for the European Patent Office.

Bradley et al. (2015) employ country-level data on patent applications filed at all major international patent offices and investigate the impact of an IP Box implementation on a country’s innovation. The authors find that on average a one percentage point decrease in the tax rate on patent income leads to a 3% increase in the new patent applications. However, Bradley et al. (2015) note that an increase in patent applications following an implementation of an IP Box does not necessarily imply an increase in innovation. They argue that an IP Box may encourage the patenting of pre-existing unpatented intangibles in addition to incentivizing new research activity.

Alstadsæter et al. (2015) and Dudar et al. (2015) segregate various attributes of IP Boxes and investigate their potential effects. Dudar et al. (2015) conclude that IP Boxes that recognize acquired intellectual property are indeed likely to attract royalty inflows into the countries of their implementation. However, the authors do not find a similar result for the IP Boxes applicable exclusively to self-developed intangibles and therefore they argue that multinationals might use certain types of IP Boxes as a means of profit shifting rather than a tool for boosting their innovation. Alstadsæter et al. (2015) conduct a detailed empirical investigation of the effects that IP Boxes have on a firm's patenting and its actual R&D activity. In line with previous studies, they find that IP Boxes have a strong effect on attracting patents, especially those of high quality. Consistent with Dudar et al. (2015), the authors find that the effect is stronger for IP Boxes that are applicable to acquired intangible assets. Furthermore, Alstadsæter et al. (2015) find that the existence of an IP Box encourages multinationals to relocate their patents without a corresponding increase in the number of inventors or a shift in research activities. Once again, this implies that IP Boxes do not provide enough incentives for companies to conduct local research and multinationals might view them as a means of profit shifting instead.

The empirical evidence on the effectiveness of IP Boxes shows that this type of R&D tax incentives is likely to be used for profit shifting rather than to increase real R&D activity. However, it is worth noting that one of the largest loopholes in the construction of IP Boxes is about to change. This is because the misuse of IP Boxes for profit shifting is possible primarily in the cases where not only self-developed but also acquired intangibles are eligible for a preferential tax treatment. Hence, companies may develop an intangible in a high-tax country and then register it in a country with an IP Box just to take advantage of the reduced taxation of income generated by this asset. However, as mentioned in section 2.2.2, the OECD now requires all existing and planned IP Boxes to follow the Nexus Approach, according to which IP Boxes should favor only intangible assets that were locally developed.[9]

In summary, the empirical evidence on input-oriented R&D tax incentives, such as tax credits or tax super-deductions, is extensive and has a long history. The authors in this field of research

[9] See OECD (2015).

find a strong positive effect of introducing or changing input-oriented fiscal incentives on the innovative activity of companies and this effect is of around the same magnitude in the earlier and more recent studies. In contrast, the literature on output-oriented R&D tax incentives is rather limited, because IP Boxes are fairly new regulations. Here, the authors usually find a positive effect of IP Boxes on a number of patents held in a country. However, as yet there is no robust evidence to show that an increase in the real R&D activity is caused by the introduction of an IP Box. Therefore, multinationals might view output-oriented R&D tax incentives not only as a way of fostering research and development but also as a means of tax planning.

4 The Use of R&D Tax Incentives in Tax Planning: A Theoretical Analysis

The previous two sections have introduced the main types of R&D tax incentives and discussed the outcomes of their implementation. The primary aim of this part of the paper is to analyze a less researched aspect of R&D tax support; namely, its potential use by multinational enterprises for tax planning. Thus, this section initially explains a standard set-up of the Devereux and Griffith model[10] and goes on to incorporate input- and output-oriented R&D tax incentives into the model, following the framework developed by Spengel and Elschner (2010) and Evers et al. (2015). Furthermore, two main settings are identified in our theoretical analysis: to begin with, a domestic investment case is presented, in which an intangible asset is developed and afterwards kept in the same country. Following on from this, a cross-border investment scenario is introduced, where an intangible asset is developed in one country and then sold to another one. The scope of our analysis covers the EU and EFTA member states in 2012.

4.1 Domestic Investment

4.1.1 Devereux and Griffith Model for Calculating Effective Tax Burden

Statutory corporate income tax rates are usually inadequate in capturing the true tax burden that an investing company faces. Therefore, there are several theoretical approaches to measure effective tax rates. For example, Devereux and Griffith (1999, 2003) expand on the earlier work by Jorgensen (1963), Hall and Jorgensen (1967), as well as King and Fullerton (1984) and

[10] See Devereux and Griffith (1999, 2003).

formulate a model that incorporates various aspects of a tax system and therefore reflects a country's effective corporate tax burden.

The key assumptions of the Devereux and Griffith model comprise perfect capital mobility under certainty and a successful outcome of real investment. Furthermore, the Devereux and Griffith approach is based on the assumption of a hypothetical investment that takes place in one period and generates returns in the next period. In a standard setting of the model, it is assumed that the investment flows into five different assets such as machinery, industrial buildings, financial assets, inventory, and intangible assets. However, in line with Evers and Spengel (2014) this study focuses only on the investment in an intangible asset, namely a self-developed patent. Furthermore, a standard case of the Devereux and Griffith approach incorporates three different sources of investment financing such as retained earnings, borrowed capital, and new equity. Referring to Evers and Spengel (2014) and for reasons of simplification, this study assumes that a patent is financed only by the means of equity. Moreover, it is assumed that R&D expenditure only consists of current R&D expenses, such as costs of R&D personnel. This assumption is plausible, since according to the OECD data on R&D spending, during the last few years current expenses constituted the majority of the total expenditure on research and development in most OECD countries.[11] Table 5 summarizes the most important assumptions of the Devereux and Griffith model and gives an overview of economic parameters applied in our study.[12]

Table 5. Summary of the Assumptions

Assumption on		Value
Legal form		Corporation
Industry		Manufacturing industry
Economic good		A self-developed patent
Source of financing		Equity
Economic depreciation	δ	Declining 15.35%
Real market interest rate	r	5%
Inflation rate	π	2%
Nominal interest rate	i	7.1%[1]
Real pre-tax return	p	20%
Useful life of an asset	ul	10 years

Notes: [1]$i = (1 + r)(1 + \pi) - 1$. The assumptions about economic parameters and depreciation rules are based on the ZEW work on effective tax rates.[13]

[11] See OECD (2016a).
[12] The robustness of the economic parameters in the Devereux and Griffith model has been tested in several studies (see European Commission/ZEW (2016)).
[13] See ZEW (2016).

The Devereux and Griffith approach allows us to calculate several measures of the effective tax burden. For instance, the cost of capital and the effective marginal tax rate (EMTR) show an effective taxation of a marginal investment. The net present value (NPV) of a marginal investment is equal to zero, which implies that the returns from this investment are just sufficient but do not exceed the returns of an alternative capital-market investment.[14] However, since this study concentrates on modelling tax planning opportunities of profitable multinational firms, we assume that a company's investment is lucrative. Therefore, we rely on calculating and comparing the effective average tax rates (EATRs), which show an effective tax burden on profitable investments and are relevant for a firm's investment location decisions. As shown in equation 2, EATR is calculated as a percentage difference between the net present value of an investment in the absence and in the presence of taxation.

$$EATR = (R^{*} - R)/\left(\frac{p}{(1+r)}\right) \tag{2}$$

In equation 2, R^{*} represents the net present value of an investment in the absence of taxes and R shows its NPV in the presence of taxation. The denominator represents the NPV of a total pre-tax income stream net of the rate of return. The net present value in the presence of taxation R is in turn calculated as follows:[15]

$$\mathrm{R} = \underbrace{-(1 - \mathrm{A})}_{\substack{\text{R\&D expenses, tax} \\ \text{depreciation}}} + \underbrace{\frac{(p+\delta)(1+\pi)}{(1+i)}(1-\tau)}_{\substack{\text{Returns generated} \\ \text{by a patent}}} + \underbrace{\frac{(1-\delta)(1+\pi)}{(1+i)}(1-A)}_{\text{Reduction in capital stock}} \tag{3}$$

As noted above, the Devereux and Griffith model is based on the assumption of a hypothetical investment that lasts two periods. The first term of equation 3 reflects the investment implemented in the first period, with A denoting the tax allowances. The next two terms represent the changes in the second period of a hypothetical investment. Hence, the second term shows the returns from the investment, whereby p represents a real return on investment, δ stands for the cost of depreciation, π denotes the rate of inflation, i denotes the interest rate, and τ represents the tax rate. Finally, the third term shows a reduction in the capital stock to its

[14] In this study, an alternative capital-market investment is a financial asset that yields a real market interest rate (which is equal to 5%, as shown in Table 5).
[15] For more details regarding the model, see Devereux and Griffith (1999, 2003), Spengel and Lammersen (2001), Schreiber et al. (2002), and Evers et al. (2015).

initial level, so that the stock of capital remains unchanged between the two periods. After the calculation of the after-tax net present value of an investment, we compute the effective average tax rate using equation 2.

Furthermore, in Belgium and Liechtenstein a notional interest deduction (NID) for equity capital is available. This tax instrument allows companies to deduct a certain percentage of the qualifying equity capital from their taxable profits. The objective of NID is to even out the tax treatment of two major sources of investment financing – equity and debt. From a tax point of view, debt might be seen as a preferable financing way compared to equity, because interest payments are tax deductible in most countries and therefore minimize a company's overall tax liability. NID gives a similar kind of advantage to equity financing. This tax measure is incorporated into the Devereux and Griffith model by adding NID expressed in equation 4 to equation 3. In equation 4, i^{NID}represents the notional interest rate, with other terms corresponding to the ones in equation 3.

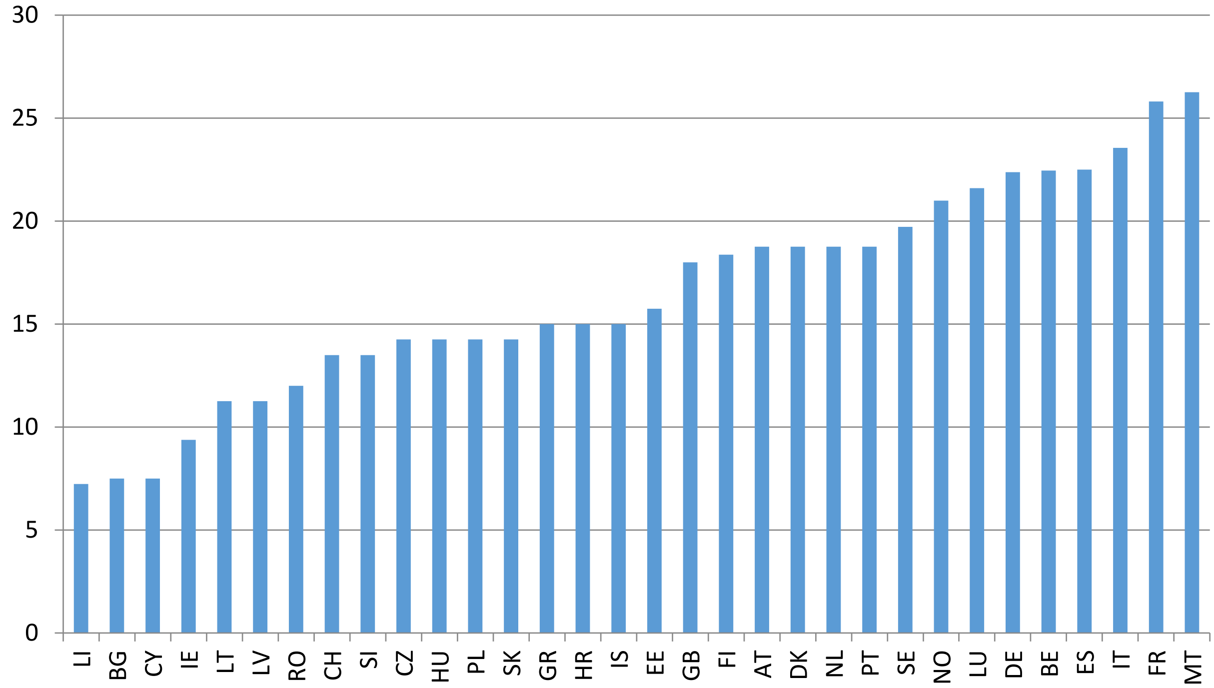
$$NID = \frac{(1-A)(i^{NID}\tau)}{1+i} \tag{4}$$

Figure 2 summarizes effective average tax rates in Europe in 2012, which we have calculated using the Devereux and Griffith model. These tax rates represent the effective tax burden that a large company faces when developing and subsequently holding a patent. The results presented in Figure 2 were calculated without the consideration of any available R&D tax incentives. According to Figure 2, the EATRs of the EU and EFTA member states range from 7.2% in Liechtenstein to 25.8% in France and 26.3% in Malta. The Eastern European countries along with Liechtenstein, Ireland, and Switzerland (Kanton Nidwalden) offer the lowest tax burden for companies developing a patent in Europe. By contrast, the western and northern European countries along with Malta appear to have comparatively high effective tax rates.

4.1.2 Incorporating R&D Tax Incentives into the Devereux and Griffith Model

This section covers the conceptual framework developed by Spengel and Elschner (2010) and Evers et al. (2015) to incorporate input- and output-oriented R&D tax incentives from Tables 1 and 2 into the Devereux and Griffith model. It is assumed in the model that a large multinational corporation carries out a hypothetical investment and for this reason only R&D tax incentives for large firms are considered here. In addition, we assume that a hypothetical

Figure 2. Effective Average Tax Rates in Europe, Domestic Investment, 2012, %



Notes: The rates represent an effective tax burden of developing and holding only one asset – a patent. A regular tax system, no R&D tax incentives are considered here. Country codes and the corresponding country names are in the appendix.

investment is profitable and thus the R&D tax incentives in the case of losses are not taken into account. Furthermore, it is assumed that the investment only consists of current and not capital expenditure and therefore only the incentives that apply to current expenses on research and development are taken into consideration. As discussed in section 4.1.1, this type of expenses constitutes the majority of R&D spending in the OECD countries.[16]

We incorporate the input- and output-oriented R&D tax incentives into the Devereux and Griffith methodology through the alterations of factor A, which represents tax allowances on an asset. As mentioned in section 2.3.1, most countries do not require a mandatory capitalization of self-created intangible assets for tax purposes and allow an immediate deduction of R&D expenditure at the regular corporate income tax rate. For simplification reasons, we assume that this rule applies to all countries under consideration[17] and on this basis factor A is defined in the absence of R&D tax incentives as follows:

$$A = \varphi_0 \, \tau \tag{5}$$

[16] In addition, we do not consider incentives that have incremental character.
[17] This assumption has also been made by Evers and Spengel (2014).

In equation 5, φ_0 represents a share of R&D expenses that are immediately deductible. In all countries analyzed in our study, it is equal to 100%. τ denotes statutory tax rate on corporate income.

4.1.2.1 Input-Oriented R&D Tax Incentives

As previously mentioned, this study is based on the assumption that R&D expenses of a model company consist of current and not capital expenditure. Therefore, this section focuses on using the framework developed by Spengel and Elschner (2010) to include input-oriented R&D tax incentives that apply to current expenses such as tax credits and tax super-deductions in the Devereux and Griffith model. For example, if a tax credit applies, A in equation 3 is defined as follows:

$$A = \varphi_0 \, \tau + \phi \qquad (6)$$

Equation 6 is similar to equation 5, except it includes factor ϕ, which represents the amount of a tax credit. As a result, a tax credit is subtracted from the company's tax liability. In the case of a tax deduction that exceeds the usual 100% (also known as a super-deduction), tax allowance A can be expressed this way in equation 3:

$$A = \varphi_0 \, \tau \, (1 + \gamma) \qquad (7)$$

where γ represents a factor of super-deduction. In contrast to a tax credit, a tax super-deduction reduced not the company's tax liability but rather its taxable income. If a country offers both types of input-oriented tax incentives, namely a tax credit and a tax super-deduction, they are combined as follows:[18]

$$A = \varphi_0 \, \tau \, (1 + \gamma) + \phi \qquad (8)$$

4.1.2.2 Output-Oriented R&D Tax Incentives

This part of the analysis incorporates IP Box regimes into the Devereux and Griffith model following the approach suggested by Evers et al. (2015). The presence of an IP Box in a country alters equation 3 in two ways. First, the reduced IP Box tax rate τ^{IP} applies to the profits

[18] See Spengel and Elschner (2010) for further details on modelling input-oriented R&D tax incentives in the Devereux and Griffith model.

generated by an intangible asset instead of the statutory CIT rate τ. Secondly, it changes tax allowance A in a similar way as the input-oriented R&D incentives. Factor A in equation 3 depends on how the R&D expenditure is treated within an IP Box. According to Table 2, some countries require a recapture of the R&D expenses which occurred in the past, whereas other countries do not. If no recapture is enforced, factor A is defined through equation 5. By contrast, if a recapture mechanism is present, the past R&D expenses cannot be deducted at the standard CIT rate and have to be either capitalized or deducted in accordance with the threshold approach. If R&D spending is recaptured according to a threshold approach, then factor A is defined through equation 5; however, instead of the standard CIT rate τ, a reduced IP Box tax rate τ^{IP} enters the formula. In some countries, previous R&D expenses have to be capitalized and amortized over the useful life of an intangible, in which case A is defined as follows:

$$A = \varphi_0 \tau - \varphi_0 \tau + \tau^{IP} \varphi \sum_{t=1}^{ul} \left(\frac{1}{1+i}\right)^t \quad (9)$$

In equation 9, R&D expenses are capitalized at the IP Box tax rate τ^{IP} in accordance with factor φ, which represents the percentagewise amortization rate in period *t*. As shown in Table 5, we assume that the useful life of a patent ul equals 10 years. Since φ is defined as $1/ul$, this parameter amounts to 10% in our analysis.

4.1.2.3 A Combination of Input- and Output-Oriented R&D Tax Incentives

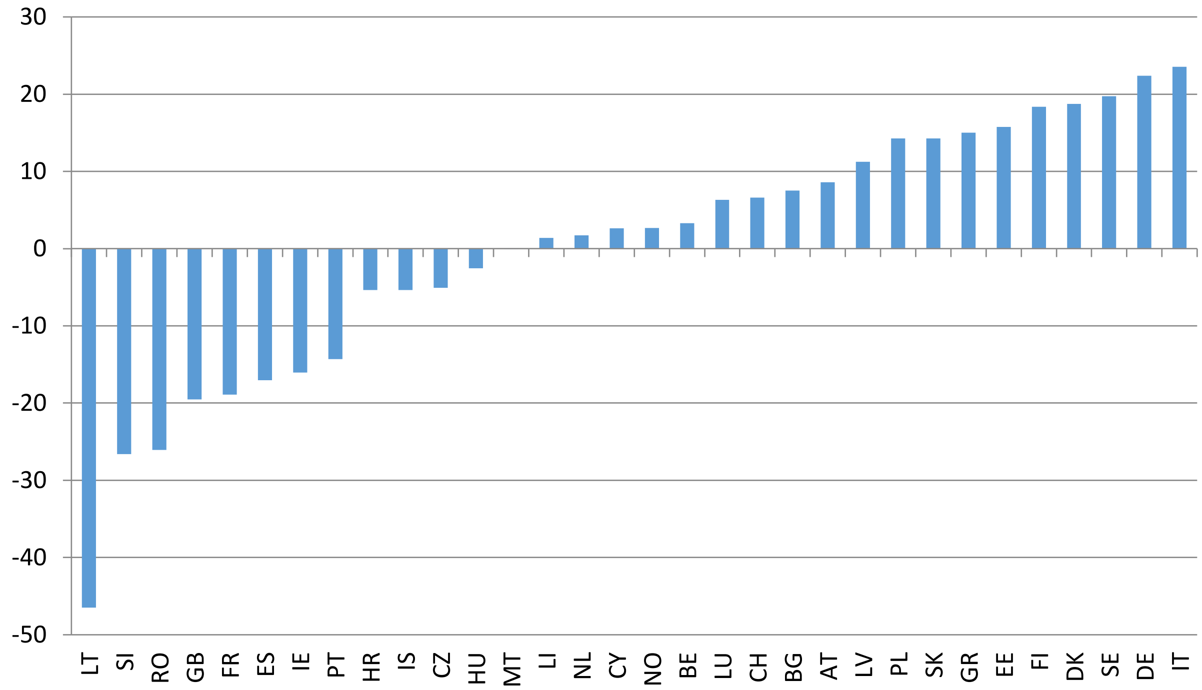
According to Evers et al. (2015), all countries except Malta allow the application of both input- and output-oriented R&D tax incentives.[19] If this is the case, factor A in equation 3 depends simultaneously on a country's tax credit, super-deduction, as well as on its IP Box. For example, if an IP Box does not require a recapture of the past R&D expenses, parameter A is equal to the one defined in equation 8. If the recapture is implemented in line with a threshold approach, it is also calculated as the one defined in equation 8 with the statutory CIT rate τ being replaced by a reduced IP Box tax rate τ^{IP}. If a recapture of the previous R&D expenditure occurs through their capitalization, equations 8 and 9 are combined as shown in equation 10.

$$A = \varphi_0 \tau - \varphi_0 \tau + (\tau^{IP} (1+\gamma) + \phi) \varphi \sum_{t=1}^{ul} \left(\frac{1}{1+i}\right)^t \quad (10)$$

[19] See Evers et al. (2015), p. 512.

Figure 3 presents the results of using the Devereux and Griffith model to calculate the effective average tax rates in the EU and EFTA member states in 2012. In contrast to Figure 2, Figure 3 illustrates not just a tax burden under the regular tax system but rather an effective taxation after incorporating all existing input- and output-oriented R&D tax incentives. If a country offers both input- and output-oriented incentives, they are combined as described above.[20] Figure 3 shows substantially lower effective average tax rates than Figure 2 in all countries with R&D tax incentives. There are exceptions to this, whereby the effective tax burden remains the same in Germany and Estonia, where no fiscal incentives are in place. Hence, Italy and Germany become countries with the highest effective tax rates once R&D incentives are considered.[21] Moreover, it is worth noting that some countries acquire a negative EATR when tax incentives are incorporated into the model. The negative values of the effective average tax burden imply that the tax treatment provides a subsidy for developing and holding a patent.

Figure 3. Effective Average Tax Rates in Europe (with R&D Tax Incentives), Domestic Investment, 2012, %



Notes: The rates represent an effective tax burden of developing and holding only one asset – a patent. Input- and output-oriented R&D tax incentives are included. Country codes and the corresponding country names are in the appendix.

[20] Since Malta is the only country that does not allow a combination of input- and output-oriented incentives, we assume that a hypothetical firm opts for an IP Box in this country. This is because an IP Box leads to a lower effective tax burden than the Maltese input-oriented tax incentives.

[21] Italy has introduced an IP Box in 2015, which implies that Germany currently has the highest effective taxation of R&D once fiscal incentives for research and development are considered in the Devereux and Griffith model.

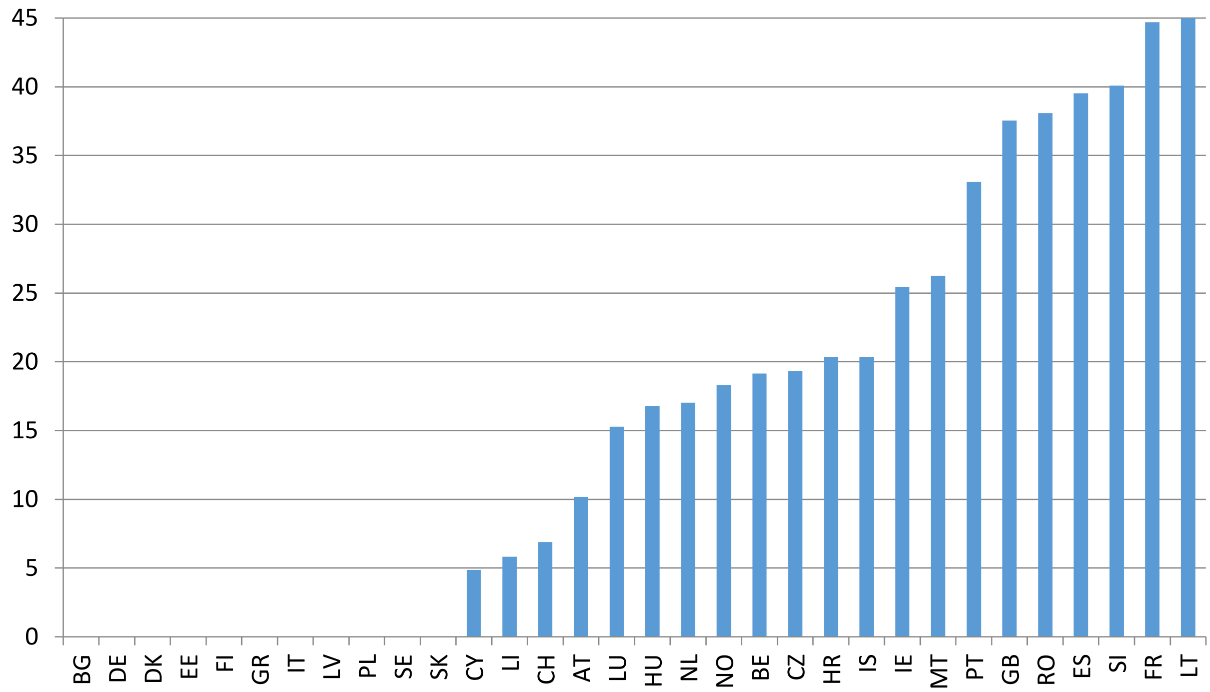
Our measure of the effective tax burden after the consideration of R&D tax incentives is comparable to the B-Index discussed in section 3.1.1. Warda (2001) has developed this measure and multiple research papers have calculated it for various countries, industries, firm sizes, and time periods (see as examples: Ernst and Spengel (2011), Thomson (2013), and Chen and Dauchy (2015)). As Spengel and Elschner (2010) note, the OECD also uses the B-Index in order to compare the attractiveness of OECD countries for R&D investment. The B-Index is calculated using the formula presented in equation 1. As explained in section 3.1.1, if an R&D investment is fully expensed in a given fiscal year, then the B-Index is equal to one. However, if a country offers a super-deduction which allows a double deduction of the actual R&D expenditure, the B-Index will be smaller than one. Therefore, the B-Index reflects the costs of research and development and its lower values correspond to a more attractive tax system for R&D investment. The main difference between the B-Index and our measure of an effective tax burden after the consideration of R&D tax incentives is the coverage of R&D tax incentives. The B-Index concentrates on input-oriented R&D tax incentives, whereas the approach used in this study also incorporates output-oriented incentives and additionally allows for a combination of the two. Furthermore, we rely on the theoretical framework of Devereux and Griffith (1999, 2003), in which a transaction of a patent from one firm to another can be modelled in a cross-border investment case in addition to the domestic investment scenario reflected in the B-Index.

4.1.3 The Impact of R&D Tax Incentives on Effective Tax Burdens

Figure 4 shows how much the effective average tax rates are reduced by once input- and output-oriented R&D tax incentives are introduced in the Devereux and Griffith Model. According to Figure 4, R&D tax incentives lead to the largest decrease (in absolute terms) in effective tax rates in Lithuania, France, Slovenia, and Spain. It should be pointed out that France and Spain offer generous R&D tax credits as well as IP Boxes. The combination of these input- and output-oriented R&D incentives results in a large tax shield for companies and leads to EATRs acquiring negative values. Lithuania and Slovenia have relatively low EATRs under their regular tax systems, as Figure 2 shows. However, taking into account the R&D super-deductions of 300% in Lithuania and 140% in Slovenia leads to an even further decrease of the effective tax rates in these countries. The EATR reduction in Malta is solely due to an IP Box regime, since the input-oriented incentives are not taken into consideration in this country, as discussed in the previous section. In summary, Figure 4 demonstrates that a significant reduction in the effective tax rate can result from either input- or output-oriented R&D tax incentives as well as from their combination.

Some countries do not show any decrease in the effective average tax rates after the R&D tax incentives are considered. Germany, Greece, Estonia, Latvia, Slovakia, and Sweden did not offer any fiscal incentives in 2012, which means that their EATRs under a regular tax system are equal to the EATRs that are calculated after taking R&D tax incentives into consideration. In addition, Bulgaria, Denmark, Italy, Finland, and Poland offer input-oriented R&D tax incentives, which are not taken into account by the model presented in this study because these incentives either apply to capital expenses (Bulgaria and Finland), have a purely incremental character (Italy), or are not available for all firms (Denmark and Poland).

Figure 4. Reductions in EATRs after Including R&D Tax Incentives into the Devereux and Griffith Model, Domestic Investment, Percentage Points



Notes: The figure shows the differences between EATRs in Figure 2 and EATRs in Figure 3. It illustrates how much the effective tax rates are reduced by when R&D tax incentives are introduced in the Devereux and Griffith model. Country codes and the corresponding country names are in the appendix.

4.2 Cross-Border Investment

4.2.1 Devereux and Griffith Model for Calculating Effective Tax Burden

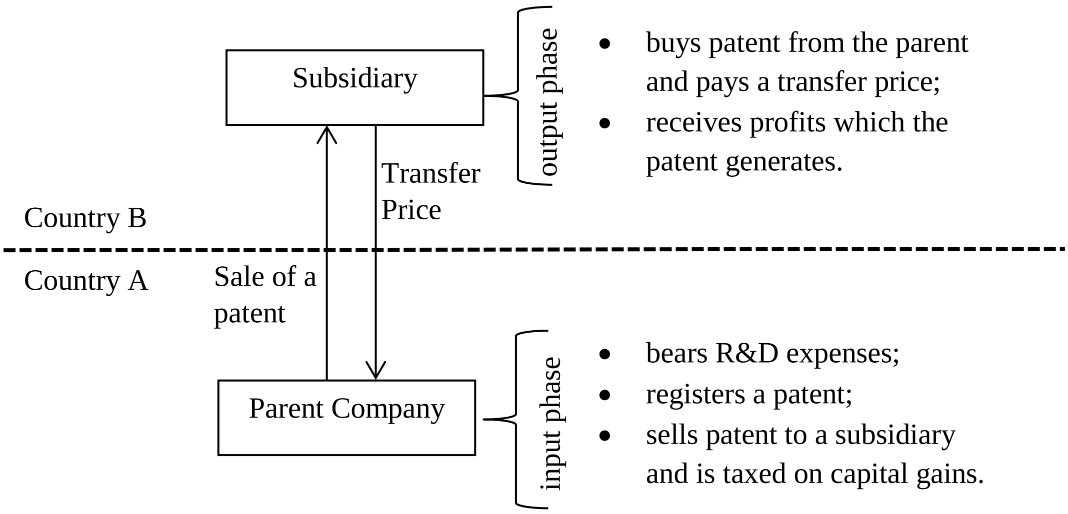
The calculation of effective average tax rates across the EU and EFTA member states in the case of a domestic investment has been discussed in the previous section. It was assumed that the input and output phases of an R&D process occur in the same country. However, the main aim of this study is to investigate whether R&D tax incentives can be used as a means of tax planning. According to Arginelli (2015), input-oriented R&D tax incentives do not always lead to an increase in a company's taxable income, productivity, or its employment. The author argues that this is because intangibles created in a country that provides generous input-oriented tax incentives might be transferred abroad or be used in the production process in other countries. Fuest et al. (2013) give an overview of profit shifting and its main financial and non-financial channels. The authors argue that a strategic location or relocation of intangible assets plays an important role in tax avoidance and aggressive tax planning[22] of multinational firms. For this reason, this section focuses on calculating the effective tax burden in the case of a cross-border sale of an intangible asset. The sale of a patent implies a transfer of its economic and legal ownership from one company to another.[23] If the effective tax burden of a multinational firm decreases after it sets apart the location where the patent was created from the location where its profits are generated, an MNE might use various input- and output-oriented R&D tax incentives for tax planning.

Figure 5 demonstrates the structure of a model company, whose effective cross-border tax burden is calculated using the extended Devereux and Griffith approach. The assumption is that the parent company and its subsidiary are located in two different countries (A and B). The input phase of an R&D process occurs at the parent firm in country A, which develops a patent and therefore bears the associated R&D expenditure and financial risks. Once the patent has been created, it is registered and sold to a subsidiary in country B. In most countries, it is a general requirement that a capital gains tax is paid on the transfer price that the parent firm receives. This tax rate usually equals a country's statutory corporate income tax rate. As a result of the transaction shown in Figure 5, the output phase of an R&D process takes place at the subsidiary in country B. Hence, if a patent generates royalties or license fees, the subsidiary receives these payments and includes them into its tax base. From a tax perspective, this procedure gives the multinational an incentive to develop a patent in a high-tax country, where it can reduce its tax liability by deducting the R&D expenditure. The patent can then be transferred to the subsidiary in a low-tax jurisdiction, which would profit from a beneficial

[22] See Piantavigna (2017) for the definition and discussion of these terms.
[23] It is assumed that dividends are exempt from withholding and corporate income taxes. This assumption is made towards countries in the EU and EFTA due to the EU Parent and Subsidiary Directive (see European Commission (2003)).

taxation of the profits generated by the intangible. Such a separation of the places where a patent is developed and held could lead to a significant reduction in the MNE's overall tax liability.

Figure 5. Structure of a Model Multinational Company



In order to calculate an effective tax burden of the multinational company presented in Figure 5 by using the Devereux and Griffith model, we have to adjust equation 2. The adjustment should reflect the deduction of R&D expenses by the parent, the taxation of profits generated by an asset at the subsidiary, as well as the taxation of a transactional sale. This is done in equation 11.

$$R = \overbrace{-\left(1 - A_P - A_S^{TP}\right)}^{\textit{R\&D expenses, tax depreciation}} + \overbrace{\frac{(p+\delta)\,(1+\pi)}{(1+i)}\,(1-\tau_s)}^{\textit{Returns generated by a patent}} - \overbrace{\tau_p\,TP}^{\textit{Capital gains taxation}} + \underbrace{+\frac{(1-\delta)\,(1+\pi)}{(1+i)}\left(1 - A_P - A_S^{TP} + \tau_p TP\right)}_{\textit{Reduction in capital stock}} \quad (11)$$

Equation 11 mirrors equation 2 and includes a few new components at the same time. For instance, the first term of the equation reflects not only the treatment of R&D expenses at the parent's level A_P but also the tax depreciation of the patent at the subsidiary A_S^{TP}, since acquired intangible assets have to be capitalized in countries under analysis. As shown in Figure 5, the parent sells the patent to the subsidiary after it has been developed. Therefore, the second term of equation 11 shows the treatment of the returns generated by a patent in the country of the subsidiary. For example, τ_s represents the income tax rate that applies in the subsidiary's host country and corresponds to the ordinary CIT rate in most cases. However, if a subsidiary's country offers an IP Box that is applicable to acquired intangibles, then a reduced tax rate applies to the income generated by the acquired patent.

Furthermore, the sale of a patent triggers capital gains taxation, which is reflected in the third term of equation 11. Here, τ_p stands for the capital gains tax in the parent's country and TP represents the transfer price on this transaction. Table 6 summarizes the effective capital gains tax rates that apply in the countries under analysis. According to Table 6, the statutory corporate income tax rate is levied in most countries on the sale price of a patent. However, a reduced capital gains tax applies in some countries that offer an IP Box.

Table 6. An Overview of Capital Gains Tax Rates on Selling a Patent, 2012

	Tax Rate, %		Tax Rate, %
Austria	25	Latvia	15
Belgium	33.9	Liechtenstein	2.5
Bulgaria	10	Lithuania	15
Croatia	20	Luxembourg	5.9
Cyprus	2.5	Malta	35
Czech Republic	19	Netherlands	5
Denmark	25	Norway	28
Estonia	21	Poland	19
Finland	24.5	Portugal	25
France	34.4	Romania	16
Germany	29.8[1]	Slovakia	19
Greece	20	Slovenia	18
Hungary	0[2]	Spain	30[3]
Iceland	20	Sweden	26.3
Ireland	12.5	Switzerland	8.8[4]
Italy	31.4	UK	10

Notes: [1]Includes 15% CIT, 14% trade tax rate, and 5.5% solidarity surcharge. [2]Capital gains from intangible assets of Hungarian taxpayers are tax exempt if reported to tax authorities and after holding for a period of 1 year (does not apply for repurchased intangibles that are already subject to an exemption). [3]The reduced rate of 11.2% applies if transfer is carried out between independent entities and if there are valid business reasons for the transaction. [4]The rate refers to the canton of Nidwalden.

As for the transfer price TP, it is defined following Evers and Spengel (2014) as:

$$TP = \alpha(p + \delta)\frac{(1 + \pi)}{(i + \delta * (1 + \pi) - \pi)} \tag{12}$$

Equation 12 includes economic parameters of the Devereux and Griffith model shown in Table 5 and an additional parameter α, which stands for the share of fair value. If α is larger or smaller than one, the transfer price TP is higher or lower than the fair price according to the arm's length principle. In this study, it is assumed that α is equal to one and so that the transfer price is fair.[24] The last term of equation 11 represents a reduction in the stock of capital, which is similar to equation 2. All other parameters of equation 11 are the same as those described in the previous section.

The input-oriented R&D tax incentives are included in our model solely through factor A_P in equation 11. In contrast, output-oriented R&D incentives may enter equation 11 multiple times. For example, an IP Box may affect A_P if a parent firm is located in a country with an IP Box and is therefore able to benefit from a preferential tax treatment of its R&D expenditure. In addition, a reduced IP Box tax rate may enter the second term of equation 11 if an IP Box applicable to acquired intangibles exists in a country of the subsidiary. Lastly, if an IP Box offers beneficial capital gains taxation, a reduced tax rate will be used in the third term of equation 11.

Notional interest deduction is incorporated by adding NID_S to equation 11 if the parent company resides in Belgium or Lichtenstein. If the subsidiary is allowed to deduct notional interest, the calculation of NID_S is based on a subsidiary's expenses on the acquisition of a patent instead of the parent's R&D expenditure. Hence, in line with equation 3, NID_S is expressed as follows:

$$NID_S = \frac{(1 - A_S^{TP})(i^{NID}\tau_S)}{1 + i} \qquad (13)$$

Table 7 presents the effective tax rates that apply in the EU and EFTA member states in 2012 in the case of a cross-border investment. Since R&D tax incentives are not considered here, the effective tax burden represents taxation under a regular tax system. The countries listed in the first column of Table 7 represent the location of a parent firm that conducts R&D, while countries in the top row show the location of a subsidiary that receives profits generated by an intangible. To give an example, the EATR of 34.2% between Austria and Belgium implies that a parent develops a patent in Austria and sells it to a subsidiary in Belgium. A capital gains tax on this transaction is then paid in Austria. The effective average tax rates which are indicated through the diagonal line highlighted in red in Table 7 show the effective taxation in the case when a parent firm keeps the patent. These values correspond to the domestic investment scenario shown in Figure 2.

[24] See Evers and Spengel (2014) for the discussion on variations in this assumption.

Table 7. Effective Average Tax Rates in Europe, Cross-Border Investment, 2012, %

	AT	BE	BG	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GR	HR	HU	IE	IS	IT	LI	LT	LU	LV	MT	NL	NO	PL	PT	RO	SE	SI	SK
AT	18.8	34.2	24.1	28.3	24.1	28.9	34.6	32.0	29.9	34.7	31.8	37.0	31.5	29.4	29.4	28.9	25.4	29.4	35.4	23.3	26.7	34.1	26.7	37.4	32.0	33.6	28.9	32.0	27.3	32.7	28.3	28.9
BE	35.7	22.5	27.8	32.0	27.8	32.6	38.3	35.7	33.6	38.4	35.5	40.7	35.2	33.1	33.1	32.6	29.1	33.1	39.2	27.0	30.4	37.8	30.4	41.1	35.7	37.3	32.6	35.7	31.0	36.4	32.0	32.6
BG	20.8	23.0	7.5	17.1	12.8	17.6	23.4	20.8	18.7	23.5	20.5	25.8	20.3	18.1	18.1	17.6	14.1	18.1	24.2	12.1	15.5	22.8	15.5	26.1	20.8	22.4	17.6	20.8	16.0	21.5	17.1	17.6
CH	26.8	29.0	18.8	13.5	18.8	23.6	29.4	26.8	24.7	29.5	26.5	31.8	26.3	24.1	24.1	23.6	20.1	24.1	30.2	18.1	21.5	28.8	21.5	32.1	26.8	28.4	23.6	26.8	22.0	27.5	23.1	23.6
CY	15.8	18.0	7.9	12.1	7.5	12.7	18.4	15.8	13.7	18.5	15.6	20.8	15.3	13.2	13.2	12.7	9.2	13.2	19.2	7.1	10.5	17.9	10.5	21.2	15.8	17.4	12.7	15.8	11.1	16.5	12.1	12.7
CZ	27.5	29.7	19.6	23.8	19.6	14.2	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	24.4	20.9	24.9	30.9	18.8	22.2	29.6	22.2	32.9	27.5	29.1	24.4	27.5	22.8	28.2	23.8	24.4
DE	35.7	37.8	27.7	31.9	27.7	32.5	22.4	35.7	33.5	38.3	35.4	40.7	35.1	33.0	38.3	32.5	29.0	33.0	39.1	26.9	30.3	37.7	30.3	41.0	35.7	37.3	32.5	35.7	30.9	36.4	31.9	32.5
DK	32.0	34.2	24.1	28.3	24.1	28.9	34.6	18.8	29.9	34.7	31.8	37.0	31.5	29.4	29.4	28.9	25.4	29.4	35.4	23.3	26.7	34.1	26.7	37.4	32.0	33.6	28.9	32.0	27.3	32.7	28.3	28.9
EE	29.0	31.2	21.1	25.3	21.1	25.9	31.6	29.0	15.8	31.7	28.8	34.0	28.5	26.4	26.4	25.9	22.4	26.4	32.4	20.3	23.7	31.1	23.7	34.4	29.0	30.6	25.9	29.0	24.3	29.7	25.3	25.9
ES	35.8	38.0	27.8	32.1	27.8	32.6	38.4	35.8	33.7	22.5	35.5	40.8	35.3	33.1	33.1	32.6	29.1	33.1	39.2	27.1	30.5	37.8	30.5	41.1	35.8	37.4	32.6	35.8	31.0	36.5	32.1	32.6
FI	31.7	33.8	23.7	27.9	23.7	28.5	34.2	31.7	29.5	34.3	18.4	36.7	31.1	29.0	29.0	28.5	25.0	29.0	35.1	22.9	26.4	33.7	26.4	37.0	31.7	33.3	28.5	31.7	26.9	32.4	27.9	28.5
FR	39.1	41.3	31.1	35.4	31.1	35.9	41.7	39.1	37.0	41.8	38.8	25.8	38.6	36.4	36.4	35.9	32.4	36.4	42.5	30.4	33.8	41.1	33.8	44.4	39.1	40.7	35.9	39.1	34.3	39.8	35.4	35.9
GB	31.3	33.5	23.3	27.6	23.3	28.1	33.9	31.3	29.2	34.0	31.0	36.3	18.0	28.6	28.6	28.1	24.6	28.6	34.7	22.6	26.0	33.3	26.0	36.6	31.3	32.9	28.1	31.3	26.5	32.0	27.6	28.1
GR	28.3	30.5	20.3	24.6	20.3	25.1	30.9	28.3	26.2	31.0	28.0	33.3	27.8	15.0	25.6	25.1	21.6	25.6	31.7	19.6	23.0	30.3	23.0	33.6	28.3	29.9	25.1	28.3	23.5	29.0	24.6	25.1
HR	28.3	30.5	20.3	24.6	20.3	25.1	30.9	28.3	26.2	31.0	28.0	33.3	27.8	25.6	15.0	25.1	21.6	25.6	31.7	19.6	23.0	30.3	23.0	33.6	28.3	29.9	25.1	28.3	23.5	29.0	24.6	25.1
HU	27.5	29.7	19.6	23.8	19.6	24.4	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	14.2	20.9	24.9	30.9	18.8	22.2	29.6	22.2	32.9	27.5	29.1	24.4	27.5	22.8	28.2	23.8	24.4
IE	22.7	24.8	14.7	18.9	14.7	19.5	25.2	22.7	20.5	25.3	22.4	27.7	22.1	20.0	20.0	19.5	9.4	20.0	26.1	13.9	17.4	24.7	17.4	28.0	22.7	24.3	19.5	22.7	17.9	23.4	18.9	19.5
IS	28.3	30.5	20.3	24.6	20.3	25.1	30.9	28.3	26.2	31.0	28.0	33.3	27.8	25.6	25.6	25.1	21.6	15.0	31.7	19.6	23.0	30.3	23.0	33.6	28.3	29.9	25.1	28.3	23.5	29.0	24.6	25.1
IT	36.8	39.0	28.9	33.1	28.9	33.7	39.4	36.8	34.7	39.5	36.6	41.8	36.3	34.2	34.2	33.7	30.2	34.2	23.6	28.1	31.5	38.9	31.5	42.2	36.8	38.4	33.7	36.8	32.1	37.5	33.1	33.7
LI	20.5	22.7	12.5	16.8	12.5	17.3	23.1	20.5	18.4	23.2	20.3	25.5	20.0	17.9	17.9	17.3	13.9	17.9	23.9	7.2	15.2	22.5	15.2	25.8	20.5	22.1	17.3	20.5	15.7	21.2	16.8	17.3
LT	24.5	26.7	16.6	20.8	16.6	21.4	27.1	24.5	22.4	27.2	24.3	29.5	24.0	21.9	21.9	21.4	17.9	21.9	27.9	15.8	11.3	26.6	19.2	29.9	24.5	26.1	21.4	24.5	19.8	25.2	20.8	21.4
LU	20.6	22.8	12.7	16.9	12.7	17.4	23.2	20.6	18.5	23.3	20.4	25.6	20.1	18.0	18.0	17.4	14.0	18.0	24.0	11.9	15.3	21.6	15.3	25.9	20.6	22.2	17.4	20.6	15.8	21.3	16.9	17.4
LV	24.5	26.7	16.6	20.8	16.6	21.4	27.1	24.5	22.4	27.2	24.3	29.5	24.0	21.9	21.9	21.4	17.9	21.9	27.9	15.8	19.2	26.6	11.3	29.9	24.5	26.1	21.4	24.5	19.8	25.2	20.8	21.4
MT	39.5	41.7	31.6	35.8	31.6	36.4	42.1	39.5	37.4	42.2	39.3	44.5	39.0	36.9	36.9	36.4	32.9	36.9	42.9	30.8	34.2	41.6	34.2	26.3	39.5	41.1	36.4	39.5	34.8	40.2	35.8	36.4
NL	32.0	34.2	24.1	28.3	24.1	28.9	34.6	32.0	29.9	34.7	31.8	37.0	31.5	29.4	29.4	28.9	25.4	29.4	35.4	23.3	26.7	34.1	26.7	37.4	18.8	33.6	28.9	32.0	27.3	32.7	28.3	28.9
NO	34.3	36.5	26.3	30.6	26.3	31.1	36.9	34.3	32.2	37.0	34.0	39.3	33.8	31.6	31.6	31.1	27.6	31.6	37.7	25.6	29.0	36.3	29.0	39.6	34.3	21.0	31.1	34.3	29.5	35.0	30.6	31.1
PL	27.5	29.7	19.6	23.8	19.6	24.4	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	24.4	20.9	24.9	30.9	18.8	22.2	29.6	22.2	32.9	27.5	29.1	14.2	27.5	22.8	28.2	23.8	24.4
PT	32.0	34.2	24.1	28.3	24.1	28.9	34.6	32.0	29.9	34.7	31.8	37.0	31.5	29.4	29.4	28.9	25.4	29.4	35.4	23.3	26.7	34.1	26.7	37.4	32.0	33.6	28.9	18.8	27.3	32.7	28.3	28.9
RO	25.3	27.5	17.3	21.6	17.3	22.1	27.9	25.3	23.2	28.0	25.0	30.3	24.8	22.6	22.6	22.1	18.6	22.6	28.7	16.6	20.0	27.3	20.0	30.6	25.3	26.9	22.1	25.3	12.0	26.0	21.6	22.1
SE	33.0	35.2	25.0	29.3	25.0	29.8	35.6	33.0	30.9	35.7	32.8	38.0	32.5	30.4	30.4	29.8	26.4	30.4	36.4	24.3	27.7	35.0	27.7	38.3	33.0	34.6	29.8	33.0	28.2	19.7	29.3	29.8
SI	26.8	29.0	18.8	23.1	18.8	23.6	29.4	26.8	24.7	29.5	26.5	31.8	26.3	24.1	24.1	23.6	20.1	24.1	30.2	18.1	21.5	28.8	21.5	32.1	26.8	28.4	23.6	26.8	22.0	27.5	13.5	23.6
SK	27.5	29.7	19.6	23.8	19.6	24.4	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	24.4	20.9	24.9	30.9	18.8	22.2	29.6	22.2	32.9	27.5	29.1	24.4	27.5	22.8	28.2	23.8	14.2

Notes: The rates represent an effective tax burden of developing a patent in country indicated in the first column and afterwards selling it to the country shown in the top row. Values on the diagonal correspond to the domestic investment scenario presented in Figure 2. A regular tax system implies that no R&D tax incentives are considered here. Country codes and the corresponding country names are in the appendix.

Table 7 shows the effective taxation under a regular tax system, which implies that no fiscal incentives are included in the calculation of these rates. For example, if an Austrian firm conducts R&D and keeps the asset afterwards, its effective tax rate amounts to 18.8%. If a cross-border scenario is considered, as shown in Figure 5, the countries where a patent is developed and where it is possessed will differ. For instance, if an Austrian parent develops an intangible and proceeds to sell it to the subsidiary in Belgium, the effective tax burden amounts to 34.2%. The sale of a patent to a subsidiary in Bulgaria will result in an EATR of 24.1% and a sale to a subsidiary in Switzerland will result in a rate of 25.5%. In all countries, effective taxation is higher in the cross-border case compared to a domestic investment (diagonal line of Table 7). This is due to the capital gains tax, which is paid when a patent is sold from one country to another and which is why a multinational firm under a regular tax system profits the most if it keeps a patent in the country where it was developed.

4.2.2 Incorporating R&D Tax Incentives into the Devereux and Griffith Model

Table 7 contains the effective tax rates that are due under a regular tax system. By contrast, Table 8 presents the results of calculating the effective cross-border taxation of patent development and sale after taking into consideration R&D tax incentives shown in Tables 1 and 2. The difference between these two cases represents a reduction in the effective tax burden caused by the R&D tax incentives. It is important to note that in a cross-border case the input-oriented fiscal incentives are only relevant for a parent firm which conducts R&D, whereas the output-oriented incentives are relevant not only for a parent firm but also for its subsidiary which receives profits generated by a patent in the output phase. This is especially true if the country of a subsidiary offers an IP Box that is applicable to an acquired IP, therefore enabling the patent to be developed elsewhere while still receiving the benefits of a local preferential tax treatment.

In line with Table 7, the diagonal line highlighted in red in Table 8 shows the effective tax rates under the domestic investment scenario. The only difference is the inclusion of R&D tax incentives in Table 8. Hence, the values on the diagonal correspond to the ones shown in Figure 3. The EATRs that are not represented on the diagonal line reflect the effective taxation in a cross-border case. Here, countries where a patent is developed are shown on the left and countries where it is held afterwards are depicted on the top. As an example, if a patent has been developed in Austria and kept there afterwards, the EATR in this domestic investment scenario equals 8.6%. If an Austrian firm has a subsidiary in Belgium, for instance, and sells a

Table 8. Effective Average Tax Rates in Europe (with R&D Tax Incentives), Cross-Border Investment, 2012, %

	AT	BE	BG	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GR	HR	HU	IE	IS	IT	LI	LT	LU	LV	MT	NL	NO	PL	PT	RO	SE	SI	SK
AT	8.6	24.0	13.9	13.3	9.9	18.7	24.4	21.9	19.7	24.5	21.6	26.9	21.3	19.2	19.2	1.9	15.2	19.2	25.3	9.4	16.6	23.9	16.6	8.6	21.9	23.5	18.7	21.9	17.1	22.6	18.1	18.7
BE	31.3	3.3	23.3	22.7	19.3	28.1	33.9	31.3	29.2	33.9	31.0	36.3	30.8	28.6	28.6	11.3	24.6	28.6	34.7	18.9	26.0	33.3	26.0	18.0	31.3	32.9	28.1	31.3	26.5	32.0	27.6	28.1
BG	20.8	23.0	7.5	12.2	8.8	17.6	23.4	20.8	18.7	23.5	20.5	25.8	20.3	18.1	18.1	0.8	14.1	18.1	24.2	8.4	15.5	22.8	15.5	7.5	20.8	22.4	17.6	20.8	16.0	21.5	17.1	17.6
CH	10.5	12.7	2.6	6.6	-1.4	7.3	13.1	10.5	8.4	13.2	10.3	15.5	10.0	7.9	7.9	-9.4	3.9	7.9	13.9	-1.9	5.2	12.6	5.2	-2.8	10.5	12.1	7.3	10.5	5.7	11.2	6.8	7.3
CY	13.9	16.1	6.0	5.3	2.6	10.7	16.5	13.9	11.8	16.6	13.7	18.9	13.4	11.3	11.3	-6.1	7.3	11.3	17.3	5.2	8.6	16.0	8.6	0.6	13.9	15.5	10.7	13.9	9.1	14.6	10.2	10.7
CZ	8.2	10.4	0.2	-0.4	-3.8	-5.1	10.8	8.2	6.1	10.9	7.9	13.2	7.7	5.6	5.6	-11.8	1.6	5.6	11.6	-4.2	2.9	10.2	2.9	-5.1	8.2	9.8	5.0	8.2	3.4	8.9	4.5	5.0
DE	35.7	37.8	27.7	27.0	23.7	32.5	22.4	35.7	33.5	38.3	35.4	40.7	35.1	33.0	38.3	15.7	29.0	33.0	39.1	23.2	30.3	37.7	30.3	22.4	35.7	37.3	32.5	35.7	30.9	36.4	31.9	32.5
DK	32.0	34.2	24.1	23.4	20.1	28.9	34.6	18.8	29.9	34.7	31.8	37.0	31.5	29.4	29.4	12.1	25.4	29.4	35.4	19.6	26.7	34.1	26.7	18.8	32.0	33.6	28.9	32.0	27.3	32.7	28.3	28.9
EE	29.0	31.2	21.1	20.4	17.1	25.9	31.6	29.0	15.8	31.7	28.8	34.0	28.5	26.4	26.4	9.1	22.4	26.4	32.4	16.6	23.7	31.1	23.7	15.8	29.0	30.6	25.9	29.0	24.3	29.7	25.3	25.9
ES	10.4	12.5	2.4	1.7	-1.6	7.2	12.9	10.4	8.2	-17.0	10.1	15.4	9.8	7.7	7.7	-9.6	3.7	7.7	13.8	-2.1	5.0	12.4	5.0	-2.9	10.4	12.0	7.2	10.4	5.6	11.0	6.6	7.2
FI	31.7	33.8	23.7	23.1	19.7	28.5	34.2	31.7	29.5	34.3	18.4	36.7	31.1	29.0	29.0	11.7	25.0	29.0	35.1	19.2	26.4	33.7	26.4	18.4	31.7	33.3	28.5	31.7	26.9	32.4	27.9	28.5
FR	8.6	10.7	0.6	0.0	-3.4	5.4	11.1	8.6	6.4	11.2	8.3	-18.9	8.0	5.9	5.9	-11.4	1.9	5.9	12.0	-3.9	3.3	10.6	3.3	-4.7	8.6	10.2	5.4	8.6	3.8	9.3	4.8	5.4
GB	24.0	26.1	16.0	15.4	12.0	20.8	26.5	24.0	21.8	26.6	23.7	29.0	-19.5	21.3	21.3	4.0	17.3	21.3	27.4	11.5	18.7	26.0	18.7	10.7	24.0	25.6	20.8	24.0	19.2	24.7	20.2	20.8
GR	28.3	30.5	20.3	19.7	16.3	25.1	30.9	28.3	26.2	31.0	28.0	33.3	27.8	15.0	25.6	8.3	21.6	25.6	31.7	15.9	23.0	30.3	23.0	15.0	28.3	29.9	25.1	28.3	23.5	29.0	24.6	25.1
HR	7.9	10.1	0.0	-0.7	-4.0	4.8	10.5	7.9	5.8	10.6	7.7	12.9	7.4	5.3	-5.4	-12.0	1.3	5.3	11.3	-4.5	2.6	10.0	2.6	-5.4	7.9	9.5	4.8	7.9	3.2	8.6	4.2	4.8
HU	8.2	10.4	0.2	-0.4	-3.8	5.0	10.8	8.2	6.1	10.9	7.9	13.2	7.7	5.6	5.6	-2.5	1.6	5.6	11.6	-4.2	2.9	10.2	2.9	-5.1	8.2	9.8	5.0	8.2	3.4	8.9	4.5	5.0
IE	-2.8	-0.6	-10.7	-11.4	-14.7	-6.0	-0.2	-2.8	-4.9	-0.1	-3.0	2.2	-3.3	-5.4	-5.4	-22.7	-16.1	-5.4	0.6	-15.2	-8.1	-0.7	-8.1	-16.1	-2.8	-1.2	-6.0	-2.8	-7.6	-2.1	-6.5	-6.0
IS	7.9	10.1	0.0	-0.7	-4.0	4.8	10.5	7.9	5.8	10.6	7.7	12.9	7.4	5.3	5.3	-12.0	1.3	-5.4	11.3	-4.5	2.6	10.0	2.6	-5.4	7.9	9.5	4.8	7.9	3.2	8.6	4.2	4.8
IT	36.8	39.0	28.9	28.2	24.9	33.7	39.4	36.8	34.7	39.5	36.6	41.8	36.3	34.2	34.2	16.9	30.2	34.2	23.6	24.4	31.5	38.9	31.5	23.5	36.8	38.4	33.7	36.8	32.1	37.5	33.1	33.7
LI	14.7	16.9	6.7	6.1	2.7	11.5	17.3	14.7	12.6	17.4	14.4	19.7	14.2	12.0	12.0	-5.3	8.0	12.0	18.1	1.4	9.4	16.7	9.4	1.4	14.7	16.3	11.5	14.7	9.9	15.4	11.0	11.5
LT	-6.0	-3.8	-14.0	-14.6	-17.9	-9.2	-3.4	-6.0	-8.1	-3.3	-6.2	-1.0	-6.5	-8.6	-8.6	-26.0	-12.6	-8.6	-2.6	-18.4	-46.5	-4.0	-11.3	-19.3	-6.0	-4.4	-9.2	-6.0	-10.8	-5.3	-9.7	-9.2
LU	14.8	17.0	6.8	6.2	2.9	11.6	17.4	14.8	12.7	17.5	14.6	19.8	14.3	12.2	12.2	-5.2	8.2	12.2	18.2	2.4	9.5	6.3	9.5	1.5	14.8	16.4	11.6	14.8	10.0	15.5	11.1	11.6
LV	24.5	26.7	16.6	15.9	12.6	21.4	27.1	24.5	22.4	27.2	24.3	29.5	24.0	21.9	21.9	4.6	17.9	21.9	27.9	12.1	19.2	26.6	11.3	11.2	24.5	26.1	21.4	24.5	19.8	25.2	20.8	21.4
MT	13.3	15.5	5.3	4.7	1.3	10.1	15.9	13.3	11.2	16.0	13.0	18.3	12.8	10.6	10.6	-6.7	6.6	10.6	16.7	0.9	8.0	15.3	8.0	0.0	13.3	14.9	10.1	13.3	8.5	14.0	9.6	10.1
NL	15.0	17.2	7.0	6.4	3.0	11.8	17.6	15.0	12.9	17.7	14.7	20.0	14.5	12.4	12.4	-5.0	8.4	12.4	18.4	2.6	9.7	17.0	9.7	1.7	1.7	16.6	11.8	15.0	10.2	15.7	11.3	11.8
NO	16.0	18.1	8.0	7.4	4.0	12.8	18.5	16.0	13.9	18.6	15.7	21.0	15.4	13.3	13.3	-4.0	9.3	13.3	19.4	3.5	10.7	18.0	10.7	2.7	16.0	2.7	-20.8	16.0	11.2	16.7	12.3	12.8
PL	27.5	29.7	19.6	18.9	15.6	24.4	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	7.6	20.9	24.9	30.9	15.1	22.2	29.6	22.2	14.3	27.5	29.1	14.2	27.5	22.8	28.2	23.8	24.4
PT	-1.0	1.1	-9.0	-9.6	-13.0	-4.2	1.5	-1.0	-3.2	1.6	-1.3	4.0	-1.6	-3.7	-3.7	-21.0	-7.7	-3.7	2.4	-13.5	-6.3	1.0	-6.3	-14.3	-1.0	0.6	-4.2	-14.3	-5.8	-0.3	-4.7	-4.2
RO	22.0	24.2	14.1	13.4	10.1	18.8	24.6	22.0	19.9	24.7	21.8	27.0	21.5	19.4	19.4	2.1	15.4	19.4	25.4	9.6	16.7	24.1	16.7	8.7	22.0	23.6	18.8	22.0	-26.1	22.7	18.3	18.8
SE	33.0	35.2	25.0	24.4	21.1	29.8	35.6	33.0	30.9	35.7	32.8	38.0	32.5	30.4	30.4	13.0	26.4	30.4	36.4	20.6	27.7	35.0	27.7	19.7	33.0	34.6	29.8	33.0	28.2	19.7	29.3	29.8
SI	19.5	21.6	11.5	10.9	7.5	16.3	22.0	19.5	17.3	22.1	19.2	24.5	18.9	16.8	16.8	-0.5	12.8	16.8	22.9	7.0	14.2	21.5	14.2	6.2	19.5	21.1	16.3	19.5	14.7	20.2	-26.6	16.3
SK	27.5	29.7	19.6	18.9	15.6	24.4	30.1	27.5	25.4	30.2	27.3	32.5	27.0	24.9	24.9	7.6	20.9	24.9	30.9	15.1	22.2	29.6	22.2	14.3	27.5	29.1	24.4	27.5	22.8	28.2	23.8	14.2

Notes: The rates represent an effective tax burden of developing a patent in country indicated in the first column and afterwards selling it to the country shown in the top row. Values on the diagonal correspond to the domestic investment scenario presented in Figure 3. Input- and output-oriented R&D tax incentives are included. Country codes and the corresponding country names are in the appendix.

patent to this company, then the effective tax burden in this cross-border case will amount to 24%. The sale of a patent to Bulgaria will result in an EATR of 13.9% and the sale to Switzerland in an EATR of 13.3%.

4.2.3 The Impact of R&D Tax Incentives on Effective Tax Burdens

In order to see the magnitude of the advantage that R&D tax incentives are giving companies, Table 9 presents the differentials between the EATRs shown in Table 7 and Table 8. They can be interpreted as the reductions in the effective tax burden caused by R&D tax incentives. Parallel to Tables 7 and 8, the diagonal values of Table 9 show the decreases in the effective taxation under a domestic investment scenario. The non-diagonal values represent reductions in a cross-border case. For example, if an Austrian firm develops a patent and keeps it afterwards, the Austrian R&D tax credit reduces its effective tax rate by 10.2 percentage points. If this firm decides to sell the patent to a company in Belgium or Bulgaria, the effective tax burden decreases by 10.2 percentage points as well. However, if it sells the intangible to a subsidiary in Switzerland, the EATR decreases by 15.1 percentage points.

Two main conclusions can be drawn from Table 9. First, R&D tax incentives in the country of a patent's development (shown in the first column of Table 9) reduce the effective taxation of a cross-border investment. This reduction mitigates the unfavorable effect of the capital gains tax on a cross-border sale of a patent. Therefore, the separation of a patent's development from the location of its further ownership becomes more attractive for multinational enterprises when R&D tax incentives are in place. However, these incentives do not fully make up for the capital gains tax and because of this a domestic investment remains more favorable for a company than a cross-border one, as demonstrated in the case of an Austrian parent and its Belgian subsidiary. Even though the effective tax burden of a cross-border investment between Austria and Belgium is reduced by 10.2 percentage points after the introduction of an R&D tax credit (see Table 9), the effective tax rate in this cross-border case is 24% and is therefore still higher than the EATR of 8.6% under a domestic investment scenario (see Table 8).

Secondly, IP Boxes in the countries of a patent's final owner (shown in the top row of Table 9) might further reduce the effective tax burden of a cross-border investment. This occurs when the beneficial tax treatment applies to both the self-developed and acquired patents. According to Table 2, countries which offer such IP Boxes include Cyprus, Hungary, Liechtenstein, Malta, and Switzerland. These IP Boxes are so generous that the total reduction of the EATR in cross-

Table 9. Reductions in EATRs after Including R&D Tax Incentives into the Devereux and Griffith Model, Cross-Border Investment, Percentage Points

	AT	BE	BG	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GR	HR	HU	IE	IS	IT	LI	LT	LU	LV	MT	NL	NO	PL	PT	RO	SE	SI	SK
AT	10.2	10.2	10.2	15.1	14.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	27.0	10.2	10.2	10.2	13.9	10.2	10.2	10.2	28.8	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
BE	4.5	19.1	4.5	9.4	8.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	21.2	4.5	4.5	4.5	8.2	4.5	4.5	4.5	23.1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
BG	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
CH	16.3	16.3	16.3	6.9	20.2	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	33.1	16.3	16.3	16.3	20.0	16.3	16.3	16.3	34.9	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
CY	1.9	1.9	1.9	6.8	4.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	18.7	1.9	1.9	1.9	1.9	1.9	1.9	1.9	20.5	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
CZ	19.3	19.3	19.3	24.2	23.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	36.1	19.3	19.3	19.3	23.0	19.3	19.3	19.3	37.9	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
DE	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
DK	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
EE	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
ES	25.4	25.4	25.4	30.3	29.4	25.4	25.4	25.4	25.4	39.5	25.4	25.4	25.4	25.4	25.4	42.2	25.4	25.4	25.4	29.2	25.4	25.4	25.4	44.1	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
FI	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
FR	30.5	30.5	30.5	35.4	34.5	30.5	30.5	30.5	30.5	30.5	30.5	44.7	30.5	30.5	30.5	47.3	30.5	30.5	30.5	34.2	30.5	30.5	30.5	49.1	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
GB	7.3	7.3	7.3	12.2	11.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	37.5	7.3	7.3	24.1	7.3	7.3	7.3	11.0	7.3	7.3	7.3	25.9	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
GR	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
HR	20.4	20.3	20.3	25.2	24.3	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.3	20.3	20.4	37.1	20.3	20.3	20.4	24.1	20.4	20.4	20.4	39.0	20.4	20.4	20.4	20.4	20.4	20.3	20.4	20.4
HU	19.3	19.3	19.3	24.2	23.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	16.8	19.3	19.3	19.3	23.0	19.3	19.3	19.3	37.9	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
IE	25.4	25.4	25.4	30.3	29.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	42.2	25.4	25.4	25.4	29.2	25.4	25.4	25.4	44.1	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
IS	20.4	20.3	20.3	25.2	24.3	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.3	20.3	20.3	37.1	20.3	20.4	20.4	24.1	20.4	20.4	20.4	39.0	20.4	20.4	20.4	20.4	20.4	20.3	20.4	20.4
IT	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
LI	5.8	5.8	5.8	10.7	9.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	22.6	5.8	5.8	5.8	5.8	5.8	5.8	5.8	24.4	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
LT	30.5	30.5	30.5	35.4	34.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	47.3	30.5	30.5	30.5	34.2	57.7	30.5	30.5	49.1	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
LU	5.8	5.8	5.8	10.7	9.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	22.6	5.8	5.8	5.8	9.5	5.8	15.3	5.8	24.4	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
LV	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
MT	26.3	26.3	26.3	31.1	30.2	26.3	26.3	26.3	26.3	26.3	26.2	26.2	26.3	26.2	26.2	43.0	26.3	26.2	26.2	30.0	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3
NL	17.0	17.0	17.0	21.9	21.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	33.8	17.0	17.0	17.0	20.7	17.0	17.0	17.0	35.6	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
NO	18.3	18.3	18.3	23.2	22.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	35.1	18.3	18.3	18.3	22.0	18.3	18.3	18.3	36.9	18.3	18.3	51.9	18.3	18.3	18.3	18.3	18.3
PL	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
PT	33.1	33.1	33.1	38.0	37.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1	49.9	33.1	33.1	33.1	36.8	33.1	33.1	33.1	51.7	33.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1
RO	3.3	3.3	3.3	8.1	7.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	20.0	3.3	3.3	3.3	7.0	3.3	3.3	3.3	21.9	3.3	3.3	3.3	3.3	38.1	3.3	3.3	3.3
SE	-	-	-	4.9	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-
SI	7.3	7.3	7.3	12.2	11.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	24.1	7.3	7.3	7.3	11.0	7.3	7.3	7.3	25.9	7.3	7.3	7.3	7.3	7.3	7.3	40.1	7.3
SK	-	-	-	4.9	4.0	-	-	-	-	-	-	-	-	-	-	16.8	-	-	-	3.7	-	-	-	18.6	-	-	-	-	-	-	-	-

Notes: Table shows the differences between EATRs in Table 7 and EATRs in Table 8. It illustrates how much the effective tax rates are reduced by when R&D tax incentives are introduced in the Devereux and Griffith model. Values on the diagonal correspond to the domestic investment scenario shown in Figure 4. Country codes and the corresponding country names are in the appendix.

border investment often exceeds the one in a domestic investment case. For example, if an Austrian firm decides to sell a patent to its Hungarian subsidiary, the consideration of R&D tax incentives in both countries reduces the EATR by 27 percentage points (see Table 9). The effective tax burden then becomes 1.9%, which is lower than the EATR of 8.6% under a domestic investment scenario (see Table 8).

In summary, the analyses presented in sections 4.1 and 4.2 show that R&D tax incentives lower the effective tax burdens of firms. This is particularly true in relation to the domestic investment scenario, where a patent is developed and afterwards held in the same country. If a patent is sold or transferred to another country (a cross-border investment), a capital gains tax applies on this transaction to compensate for the separation between the intangible's place of development and the location of where its profits are taxed. However, even with the capital gains taxation, a multinational may still take advantage of R&D tax incentives to minimize its effective tax burden in a cross-border investment scenario. For example, input-oriented tax incentives in a parent firm's country might mitigate the unfavorable effect of a capital gains tax by lowering the effective tax burden in a cross-border investment case. Moreover, the effective tax rate in a cross-border case might total an even lower rate than the EATR in a domestic investment scenario. This occurs when both the country of a patent's developer and the country of its final owner offer generous R&D tax incentives, such as IP Boxes for acquired intangible assets. As a result, these R&D tax incentives may not only contribute to fostering research and development in the countries of their implementation but could also be used by multinational enterprises for tax planning. However, as mentioned in section 2.2.2, the OECD Nexus Approach might close this loophole in tax regulations. Countries such as Belgium, the Netherlands, and Spain have already implemented this approach within the scope of their IP Boxes and as a result they now permit preferential tax treatment only for self-developed and not acquired intellectual property.

5 The Use of R&D Tax Incentives in Tax Planning: A Quantitative Analysis

5.1 Literature Review

The previous section has pointed out that R&D tax incentives might substantially reduce effective taxation of developing and relocating a patent. As a result, these incentives provide two major advantages for companies: the first advantage is that they reduce the costs of conducting research and development. The second advantage these incentives provide is the use they have in strategically relocating intangible assets with the purpose of reducing a multinational's overall tax liability. We test this hypothesis in this section by empirically analyzing whether R&D tax incentives are used by multinational enterprises for profit shifting and in doing so we contribute to two strands of empirical literature. The first one includes studies on the effectiveness of R&D tax incentives and their influence on a firm's productivity and innovation. The second strand of literature comprises empirical papers on profit shifting by multinational enterprises, in particular by means of intellectual property.

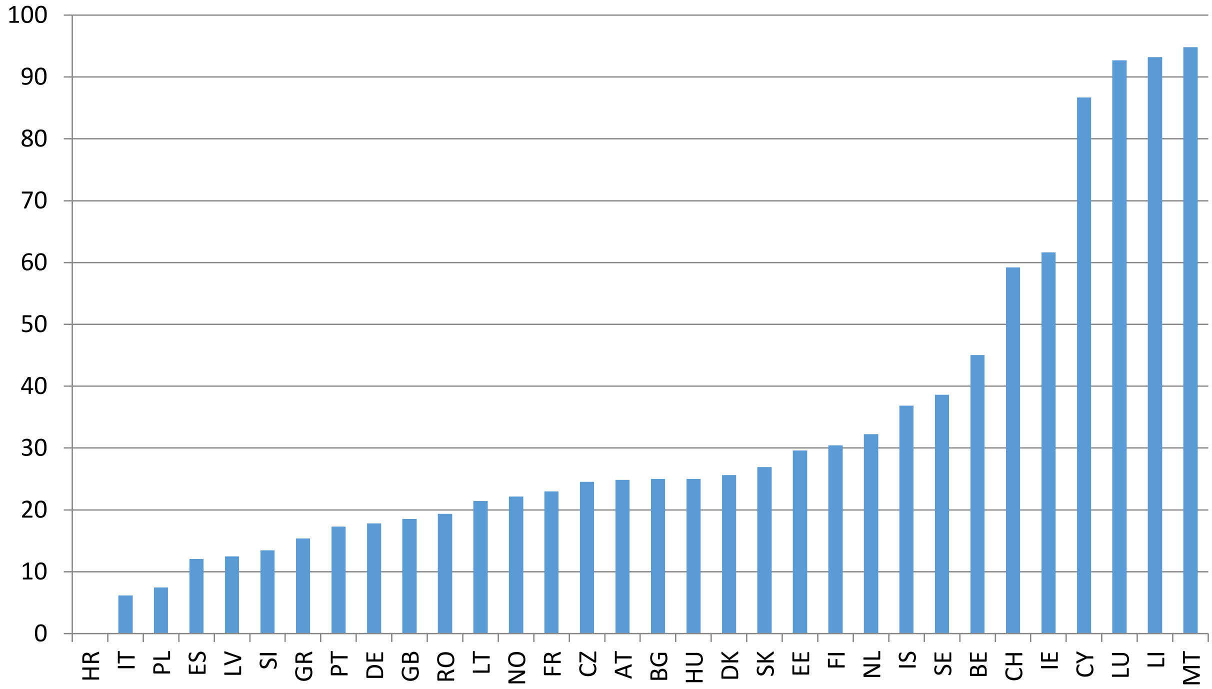
As described in section 3, Bloom et al. (2002), Baghana and Mohnen (2009), Ernst and Spengel (2011), Lokshin and Mohnen (2012), Thomson (2015), and many other studies have found a positive effect of decreasing user costs or the B-Index on R&D expenditure using firm-level or country-level data. These authors conclude that input-oriented fiscal incentives for R&D effectively foster research and development. Yang et al. (2012), Bozio et al. (2014), Kobayashi (2014), and Guceri (2017) confirm this finding by evaluating the effects of the reforms that have introduced input-oriented R&D tax incentives. By contrast, the literature on output-oriented tax incentives establishes that they have a positive effect on a firm's number of intangibles but does not confirm a simultaneous increase in real R&D activity, as Alstadsæter et al. (2015) conclude. While these studies investigate the impact of fiscal incentives on a company's innovative activity, we contribute to this literature by examining in more detail the use of tax incentives in profit shifting.

Numerous empirical and theoretical studies investigate the use of intangible assets in profit shifting. These studies argue that multinational enterprises strategically allocate intangible assets at low-tax subsidiaries in order to shift profits via royalty payments from high-tax to low-tax group members. Ernst and Spengel (2011), Karkinsky and Riedel (2012), Griffith et al. (2014), Alstadsæter et al. (2015), Böhm et al. (2015), Dinkel and Schanz (2015), and Bradley et al. (2015) investigate the association between corporate taxation and the location of intangible assets using data on patent applications at the international patent registration offices. This data contains information on companies that apply for an international protection of their inventions and therefore reveals patents' legal owners. According to these studies, an increasing statutory corporate income tax rate negatively influences the probability of patent ownership at MNE affiliates in this country. Our analysis closely relates to these studies and contributes to them by focusing not just on the strategic allocation of intellectual property but rather on the separation of IP ownership. Thus, we analyze whether, and if so, to what extent regular corporate tax systems and tax incentives for research and development influence the international collaboration in patents, which is defined as a patent's development in one country and its subsequent registration abroad.

5.2 Data

Our empirical analysis employs the OECD database *International Co-Operation in Patents*,[25] which includes bilateral data on the number of patents developed in one country and registered in another one afterwards. Following the qualitative analysis presented in the previous part of the paper, we focus on the 28 member states of the European Union and four members of the European Free Trade Association (Iceland, Liechtenstein, Norway, and Switzerland). Therefore, our sample includes 992 country-pairs and we observe the co-operation in patents between these countries in 2012 and compare it with the year 1995. Figure 6 presents descriptive statistics on international co-operation in patents in 2012.

Figure 6. A Ratio of Patents Developed Abroad in Relation to Total Patents, 2012, %



Notes: Country codes and the corresponding country names are in the appendix. Source: OECD, database *International Co-operation in Patents.*

[25] See OECD (2016b).

Figure 6 shows a ratio of patents developed abroad in relation to total patents registered in a given country. What becomes apparent from the figure is that over 80% of the total patents held in Malta, Liechtenstein, Luxembourg, and Cyprus were developed elsewhere and over 40% of patents located in Ireland, Switzerland, and Belgium originated abroad. We investigate the relationship between taxation and the country's co-operation in patents further in our empirical analysis using information on international collaboration in patents as a dependent variable. Since in our dataset there is no exchange of patents between country-pairs in 65% of cases, we are interested in analyzing the extensive margin of the co-operation in patents. Hence, the dependent variable in this case is equal to one if there is any relocation of patents between two countries and equals zero otherwise. In order to investigate the intensive margin, we additionally use a total number of patents relocated from one country to another as a dependent variable. In addition, we normalize this variable by building a ratio of patents relocated from one country to another in relation to a total number of foreign patents held by a host country.

The effective tax rates with and without considering R&D tax incentives serve as the main independent variables of interest. We extract them from Tables 7 and 8 for 2012 and additionally calculate the corresponding values for 1995. Section 4 describes in detail the calculation of effective tax burden using the Devereux and Griffith model. Apart from this, we include a few further controls into our estimation. For example, in line with Dischinger and Riedel (2011), Karkinsky and Riedel (2012), and Griffith et al. (2014), we control for the level of innovation in a country where a patent is registered. This variable is proxied by a country's total R&D expenditure, the information on which comes from the OECD database called *Gross Domestic Expenditure on R-D by Sector of Performance and Source of Funds*.[26] Following Dischinger and Riedel (2011), Ernst and Spengel (2011), Karkinsky and Riedel (2012), Ernst et al. (2014), Griffith et al. (2014), we also control for a country's market size, its wealth, and governance situation. This is done by including into the estimation *Log(Population), Log(GDP/capita)*, and *Property Rights* respectively. We collected statistics on gross domestic product (GDP) per-capita and population from the World Bank's *Development Indicators*[27] and for data on intellectual property rights protection we consulted the Heritage Foundation.[28]

Table 10 presents the key descriptive statistics of the variables that enter the regression estimation. The table is divided into two panels: Panel A shows statistics for the sample of 1995

---

[26] See OECD (2016a).
[27] See World Bank (2017).
[28] See Heritage Foundation (2017).

and Panel B presents a summary for the sample of 2012. The first three variables are used as dependent variables in different specifications. As it can be seen from the table, the first one is a binary variable and the other two are strictly positive. The maximum number of patents developed in one country and registered in another one amounts to 374 in 1995 and 1,056 in 2012, while the average equals 4.21 in 1995 and 12.17 in 2012. What these results suggest is that international co-operation in patents seems to have grown during these years.

Table 10. Descriptive Statistics

Panel A. Sample of 1995

	Obs.	Mean	Std. Dev.	Min	Max
Dummy Patents	992	0.24	0.43	0.00	1.00
Number of Patents	992	4.21	20.19	0.00	374.00
Ratio of Patents	992	0.02	0.08	0.00	1.00
EATR_regular	992	0.42	0.12	0.07	0.69
EATR_with_incentives	992	0.40	0.12	0.05	0.69
Log(R&D Exp.)	992	6.96	2.09	2.41	10.82
Log(GDP/capita)	992	9.92	0.85	8.24	11.27
Log(Population)	992	15.54	1.72	10.34	18.22
Property Rights	992	68.63	16.78	30.00	90.00

Panel B. Sample of 2012

	Obs.	Mean	Std. Dev.	Min	Max
Dummy Patents	992	0.39	0.48	0.00	1.00
Number of Patents	992	12.17	57.12	0.00	1,056.00
Ratio of Patents	992	0.02	0.06	0.00	0.50
EATR_regular	992	0.27	0.07	0.07	0.45
EATR_with_incentives	992	0.15	0.12	-0.26	0.42
Log(R&D Exp.)	992	7.75	1.85	4.18	11.32
Log(GDP/capita)	992	10.31	0.71	8.86	11.85
Log(Population)	992	15.59	1.69	10.51	18.20
Property Rights	992	72.40	18.23	30.00	90.00

Notes: EATR stands for effective average tax rate. R&D stands for research and development. GDP denotes gross domestic product.

As for the main independent variables of interest, *EATR_regular* represents the effective tax burden on a cross-border collaboration in patents. The values of this variable in 2012 are shown in Table 7 and discussed in section 4.2.2 and the values for 1995 were calculated separately. *EATR_with_incentives* represents the effective tax burden on a bilateral co-operation in patents after the consideration of R&D tax incentives. The values of this variable are shown in Table 8 for 2012 and were additionally calculated for 1995. According to Table 10, the average regular EATR decreased from 42% in 1995 to 27% in 2012. The effective tax burden after the consideration of R&D tax incentives fell from 40% in 1995 to 15% in 2012. Hence, we conclude that taxation under a regular system substantially decreased between 1995 and 2012. However, fiscal incentives for research and development have contributed to an even greater fall in the effective corporate tax burden. As for the other control variables, the average spending on R&D, GDP per-capita, population, and a level of property rights protection all increased between 1995 and 2012.

5.3 Estimation Approach

The identification strategy of our empirical analysis is based on a difference regression. In other words, we estimate the influence of the change in taxation between 1995 and 2012 on the change in the bilateral co-operation in patent development. This method enables all factors that have remained constant between the two years (such as the distance between countries, their common language, history, culture, and other factors) to be effectively controlled for and is therefore comparable with a country-pair fixed effects estimation.

5.3.1 Extensive Margin

As mentioned in the previous section, in 65% of cases there is no exchange of patents between country-pairs in our sample. Hence, we are interested in analyzing the extensive margin of co-operation in patents, which is done using the following specification:

$$B_{ij2012} - B_{ij1995} = \beta_1(\mathrm{EATR}_{\mathrm{ij2012}} - \mathrm{EATR}_{\mathrm{ij1995}}) + \beta_2 (\boldsymbol{X'}_{\mathrm{ij2012}} - \boldsymbol{X'}_{\mathrm{ij1995}}) + + (\varepsilon_{ij2012} - \varepsilon_{ij1995}) \tag{14}$$

In equation 14, B_{ijt} is a binary variable that equals one if there is any co-operation in patents between country *i* and *j* in year *t* (*t* = 1995, 2012) and zero otherwise. $EATR_{ijt}$ represents either *EATR_regular* or *EATR_with_incentives*, which measure an effective tax burden on co-operation in patents between country *i* and *j*. The first variable reflects taxation under a regular tax system without considering R&D tax incentives and the second one denotes an effective tax burden after incorporating input- and output-oriented fiscal incentives for research and development. The calculation of these variables is described in detail in section 4. $\boldsymbol{X'_{ij}}$ is a vector of the host country's characteristics such as *Log(R&D Exp.), Log(Population), Log(GDP/capita)*, and *Property Rights*. Finally, ε_{ij} is an error term.

5.3.2 Intensive Margin

As a next step, we exploit the continuous information on co-operation in patents. In this part of the analysis, the model of estimation is defined as follows:

$$Patents_{ij2012} - Patents_{ij1995} = \beta_1(\mathrm{EATR_{ij2012}} - \mathrm{EATR_{ij1995}}) + \\ + \beta_2\,(\boldsymbol{X'}_{\mathrm{ij2012}} - \boldsymbol{X'}_{\mathrm{ij1995}}) + (\varepsilon_{ij2012} - \varepsilon_{ij1995}) \tag{15}$$

In equation 15, the dependent variable $Patents_{ij}$ takes one of the following two forms: in the first form the variable equals the number of patents developed in country *i* and registered afterwards in country *j*. In the second form the variable equals the ratio of patents developed in *i* and registered in *j* in relation to the total number of patents that arise from international co-operation in patents in country *j*.[29] All other variables are identical to the ones included in equation 14.

5.4 Results

Table 11 presents results of our empirical analysis. In all specifications shown in this table, the units of observation are country-pairs. Panel A shows the outcomes of estimating equation 14, which examines the extensive margin of co-operation in patents. Panel B displays the results of estimating equation 15 and focuses on the intensive margin of international collaboration in patents. Since the dependent variable in the regressions of Panel A is binary, a Logit estimator is applied here. Columns I and II of Panel A present the outcomes of solely including the main independent variables into the estimation, while columns III and IV add further controls. According to the results, there is a negative correlation between taxation and the probability of two countries co-operating in patent development. The magnitude of the impact of regular taxation seems to be more pronounced than the influence of effective taxation after taking R&D tax incentives into account. This implies that country-pairs place greater emphasis on a regular tax system than on available R&D tax incentives when choosing a partner for collaboration in

[29] This ratio is analyzed by employing the total number of patents that arise from international co-operation in patents in country *j* as an exposure variable.

patent development. This outcome is in line with Ernst and Spengel (2011), Karkinsky and Riedel (2012), Griffith et al. (2014), Böhm et al. (2015), Dinkel and Schanz (2015), Bradley et al. (2015), and other previous studies which establish a significant negative impact of corporate income taxation on the location of intangible assets within multinational groups.

Panel B of Table 11 presents the results of analyzing the extensive margin of co-operation in patents. These calculations are carried out using the Poisson pseudo-maximum likelihood (PPML) estimator, which suits an estimation of data concentrated at zero, as Wooldridge (2002) and Westerlund and Wilhelmsson (2011) note. Columns V-VIII show the outcomes of defining the dependent variable as a number of patents developed in country *i* and registered in country *j*. Columns IX-XII present the outcomes of employing a ratio of patents originated in *i* and held in *j* in relation to a total number of patents of foreign origin registered in *j* as the dependent variable. In both cases there appears to be a negative and statistically significant correlation between taxation and the intensity of collaboration in patents. However, the economic and statistical importance of tax variables decreases once other controls are added to the specifications (see columns VII-VIII and XI-XII of Table 11).

In addition, the coefficient on $EATR_{with\_incentives}$ appears to be more negative than the coefficient on $EATR_{regular}$ once other controls are included (see columns VIII and XII). This implies that fiscal incentives play an important role in determining the intensive margin or, in other words, the intensity of co-operation in patents. As for the other control variables, expenses on research and development seem to play a significant role in determining international collaboration in patents. GDP per-capita turns out to be statistically significant only in determining the extensive margin of the co-operation and the level of property rights protection appears to matter only for the intensive margin. The size of the population does not have a statistically significant impact on the international collaboration in patents.

Table 11. Empirical Results

Panel A. Extensive Margin

	I	II	III	IV
EATR_regular	-9.342***		-3.789**	
	(1.198)		(1.497)	
EATR_with_incentives		-6.487***		-2.655**
		(0.820)		(1.105)
Log(R&D Exp.)			1.040**	0.928*
			(0.511)	(0.515)
Log(GDP/capita)			2.393*	2.373*
			(1.298)	(1.284)
Log(Population)			0.567	0.207
			(2.636)	(2.600)
Property Rights			-0.015	-0.019
			(0.018)	(0.017)
Observations	992	992	992	992

Panel B. Intensive Margin	Number of Patent Applications				Ratio of Patent Applications			
	V	VI	VII	VIII	IX	X	XI	XII
EATR_regular	-4.500***		-0.909*		-4.480***		-0.963**	
	(0.618)		(0.484)		(0.603)		(0.473)	
EATR_with_incentives		-3.353***		-1.115***		-3.321***		-1.125***
		(0.285)		(0.367)		(0.275)		(0.353)
Log(R&D Exp.)			1.007***	0.894***			1.001***	0.893***
			(0.329)	(0.305)			(0.330)	(0.304)
Log(GDP/capita)			0.793	0.505			0.726	0.441
			(0.672)	(0.650)			(0.679)	(0.648)
Log(Population)			0.809	0.682			0.843	0.733
			(0.963)	(0.839)			(0.925)	(0.808)
Property Rights			0.025***	0.025***			0.025***	0.025***
			(0.008)	(0.007)			(0.007)	(0.007)
Observations	992	992	992	992	992	992	992	992

Notes: ***, **, * indicates significance at the 1%, 5%, and 10% level. Robust standard errors are reported in parentheses. Logit model is applied in Panel A and Poisson pseudo-maximum likelihood estimator is used in Panel B. Observational units are country-pairs. The dependent variable in Panel A is binary; it equals one if there is co-operation in patens between a given country-pair and zero otherwise. The dependent variable in columns I-IV of Panel B is the number of patents that were developed in country *i* and registered in country *j*. The dependent variable in columns V-VIII of Panel B is the ratio of patents developed in country *i* and registered in country *j* in relation to a total number of patents with foreign origin registered in country *j*; this ratio is analyzed by employing the denominator as an exposure variable. *EATR_regular* and *EATR_with_incentives* are average effective tax rates on developing a patent in country *i* and holding it in country *j* afterwards; the first one does not include R&D tax incentives, whereas the second one does. *Log (R&D Exp.)* is a logarithm of a country's R&D expenditure. *Log (GDP/capita)* measures GDP per-capita. *Log (Population)* denotes a logarithm of total population. *Property Rights* represents a level of intellectual property rights protection.

6 Conclusion

The main objective of this study is to carry out a comprehensive analysis of diverse aspects of R&D tax incentives. To begin with, we examine the economic justification for the state support of research and development and conclude that this type of R&D fostering is necessary because of at least two following reasons. First, R&D causes positive spillovers, since companies may use outcomes of research and development without the possibility of any rivalry or exclusion happening. Even if the outcomes of an R&D process are not successful, there is still a positive spillover effect. Namely, other firms can learn from the unsuccessful experience and either avoid repeating the same mistake in the future or plan their research differently from the very beginning. Secondly, the issue of asymmetric information makes it difficult for creditors to finance risky R&D activities. As a consequence, it may only be low-risk R&D projects that receive financing with the other projects remaining overlooked, even if their potential returns are high.

In addition, the study concludes that fiscal incentives constitute an important part of the state support of R&D. This is because they are easier to implement and are less complex to monitor than, for example, direct R&D grants or subsidies. R&D tax incentives can be divided into two categories according to the stage of an R&D project that they support. Input-oriented incentives comprise tax credits, super-deductions, and other incentives that apply during the development phase of a research project. Output-oriented incentives include IP Boxes and apply during the second phase of an R&D process, which includes managing the profits that an intangible generates or dealing with the losses that have occurred in the case of an unsuccessful investment. We give a detailed overview of the existing input- and output-oriented R&D tax incentives in the EU and EFTA member states. The majority of these countries offer either input- or output-oriented tax incentives, while some countries have even implemented both types of incentives. By contrast, Germany, Estonia, and Sweden are currently the only countries in Europe that do not offer any R&D tax incentives.

Furthermore, the study presents a review of empirical literature on the outcomes of the implementation of input- and output-oriented R&D tax incentives. The empirical evidence on input-oriented R&D tax incentives usually points to a strong positive effect of their introduction on the innovative activity of companies. By contrast, the literature on output-oriented R&D tax incentives does not find robust evidence for an increase in the real R&D activity following an IP Box introduction. According to the literature review, multinationals might see output-oriented R&D tax incentives as a means of tax planning rather than a tool for boosting their research and development.

Moreover, we apply the Devereux and Griffith model to calculate effective average tax rates with and without the inclusion of R&D tax incentives in the EU and EFTA member states in 2012. With the help of this model, we analyze two cases of an R&D investment. First, the effective tax burden in the case of a domestic investment is calculated. Here, intellectual property is assumed to be developed and afterwards held by the same company, so that the input and output phases of an R&D process take place in the same country. Secondly, the effective taxation in the case of a cross-border investment is determined. In this case, it is assumed that an intangible asset is developed in one country and then sold abroad and because of this the input and output stages of an R&D process occur in different countries. The calculation of effective tax rates using the Devereux and Griffith model shows that R&D tax incentives substantially lower a firm's total tax burden. This is particularly the case in a domestic investment scenario. If a patent is sold or transferred to another country (a cross-border investment), a capital gains tax applies. However, even in this case input-oriented tax incentives mitigate the capital gains taxation by lowering a multinational's overall effective tax burden. Moreover, output-oriented R&D tax incentives might lower the EATR in the cross-border case even below the EATR value in a domestic investment case. This occurs when a country allows an IP Box to apply to both the self-developed and acquired intangible assets. Therefore, multinational enterprises might use IP Boxes for tax planning in addition to viewing them as a means of fostering their research and development.

Finally, we employ the OECD data on international co-operation in patents to test whether taxation has an influence on the probability (and intensity) of patents to be developed in one country and subsequently registered in another. According to our main findings, both a regular tax system and R&D tax incentives contribute to the determination of the extensive and intensive margins of the international collaboration in patents. These findings are in line with Ernst and Spengel (2011), Karkinsky and Riedel (2012), Griffith et al. (2014), Böhm et al. (2015), Dinkel and Schanz (2015), and Bradley et al. (2015) and support the main hypothesis of our study showing that firms respond to taxation and fiscal incentives by strategically allocating their patents. This once again implies that some of the R&D tax incentives might be used for tax planning rather than fostering research and development.

As for the policy applications of this study, it can be concluded that R&D tax incentives constitute a vital part of supporting innovation and research and that the design of these incentives is crucial for their economic outcomes. For example, numerous empirical studies have found that input-oriented incentives have a positive impact on real R&D activity. However, this result was not confirmed in the case of output-oriented tax incentives. Output-oriented incentives might substantially reduce the effective tax burden of a cross-border R&D investment and may therefore be used for tax planning purposes by multinational enterprises. On that account, input-oriented R&D tax incentives should be seen as a preferred instrument for fostering research and development. As for the output-oriented incentives, thorough supervision and management are required to ensure that they are used properly by multinational firms and effectively reach their aim of boosting R&D.

References

Alstadsæter, A., Barrios, S., Nicodeme, G., Skonieczna, A., and Vezzani, A. (2015), Patent Boxes Design, Patents Location and Local R&D, *European Commission Working Paper*, No. 57/2015.

Arginelli, P. (2015), Innovation through R&D Tax Incentives: Some Ideas for a Fair and Transparent Tax Policy, *World Tax Journal*, vol. 7(1), 3-71.

Atkinson, R. and Andes, S. (2011), Patent Boxes: Innovation in Tax Policy and Tax Policy for Innovation, *Information Technology & Innovation Foundation Paper*.

Baghana, R. and Mohnen, P. (2009), Effectiveness of R&D Tax Incentives in Small and Large Enterprises in Québec, *Small Business Economics*, vol. 33(1), 91-107.

Bloom, N., Griffith, R., and Van Reenen, J. (2002), Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997, *Journal of Public Economics*, vol. 85(1), 1-31.

Böhm, T., Karkinsky, T., Knoll, B., and Riedel, N. (2015), Corporate Taxes and Strategic Patent Location within Multinational Firms. In: *CESifo Area Conference on Public Sector Economics 04/2015*.

Bozio, A., Irac, D., and Py, L. (2014), Impact of Research Tax Credit on R&D and Innovation: Evidence from the 2008 French Reform, *Banque de France Working Paper: Document de Travail*, No. 532.

Bradley, S., Dauchy, E., and Robinson, L. (2015), Cross-Country Evidence on the Preliminary Effects of Patent Box Regimes on Patent Activity and Ownership, *National Tax Journal*, vol. 68(4), 1047-1072.

Castellacci, F. and Lie, C. (2015), Do the Effects of R&D Tax Credits Vary Across Industries? A Meta-Regression Analysis, *Research Policy*, vol. 44(4), 819-832.

Chen, S. and Dauchy, E. (2015, *unpublished*), International R&D Sourcing and Knowledge Spillover: Evidence from OECD Countries, available at:

file:///C:/Users/User/Downloads/Dauchy-International_R&D_Sourcing_and_Knowledge_Spillover-206%20(1).pdf

Corchuelo, B. and Martínez-Ros, E. (2010), Who Benefits from R&D Tax Policy? *Cuadernos de Economía y Direccíon de la Empresa*, vol. 13(45), 145-170.

Cunningham, P., Gök, A., and Laredo, P. (2013), The Impact of Direct Support to R&D and Innovation in Firms, *Nesta Working Paper*, No. 13/03.

Devereux, M. and Griffith, R. (1999), The Taxation of Discrete Investment Choices, *The Institute for Fiscal Studies Working Paper Series*, No. 98/16 (Revision 2).

Devereux, M. and Griffith, R. (2003), Evaluating Tax Policy for Location Decisions, *International Tax and Public Finance*, vol. 10(2), 107-126.

Dinkel, A. and Schanz, D. (2015), Tax Attractiveness and the Location of Patents, *Arqus-Diskussionsbeiträge zur Quantitativen Steuerlehre*, No. 188.

Dischinger, M. and Riedel, N. (2011), Corporate Taxes and the Location of Intangible Assets within Multinational Firms, *Journal of Public Economics*, vol. 95(7/8), 691-707.

Dudar, O., Spengel C., and Voget J. (2015), The Impact of Taxes on Bilateral Royalty Flows, *Centre for European Economic Research (ZEW) Discussion Paper*, No.15-052.

Ernst, C., Richter, K., and Riedel, N. (2014), Corporate Taxation and the Quality of Research and Development, *International Tax and Public Finance*, vol. 21(4), 694-719.

Ernst, C. and Spengel, C. (2011), Taxation, R&D Tax Incentives and Patent Application in Europe, *Centre for European Economic Research (ZEW) Discussion Paper*, No.11-024.

European Commission (2003), EU Parent and Subsidiary Directive, available at: http://ec.europa.eu/taxation_customs/business/company-tax/parent-companies-their-subsidiaries-eu-union_de

European Commission/ZEW (2016), The Effect of Inflation and Interest Rates on Forward-Looking Effective Tax Rates, EU Commission Taxation Papers Working Paper, No. 63.

Evers, L., Miller, H., and Spengel, C. (2015), Intellectual Property Box Regimes: Effective Tax Rates and Tax Policy Considerations, *International Tax and Public Finance*, vol. 22(3), 502-530.

Evers, L. and Spengel, C. (2014), Effective Tax Rates under IP Tax Planning, *Centre for European Economic Research (ZEW) Discussion Paper*, No. 14-111.

Falk, M. (2006), What Drives Business Research and Development (R&D) Intensity Across Organisation for Economic Co-Operation and Development (OECD) Countries?, *Applied Economics*, vol. 38(5), 533-547.

Fuest, C., Spengel, C., Finke, K., Heckemeyer, J., and Nusser, H. (2013), Profit Shifting and „Aggressive“ Tax Planning by Multinational Firms: Issues and Options for Reform, *World Tax Journal*, vol. 5(3), 307-324.

Gaillard-Ladinska, E., Non, M., and Straathof, B. (2015), More R&D with Tax Incentives? A Meta-Analysis, *CPB Discussion Paper*, No. 309.

Griffith, R., Miller, H., and O'Connell, M. (2014), Ownership of Intellectual Property and Corporate Taxation, *Journal of Public Economics*, vol. 112, 12-23.

Guceri, I. (2017), Will the Real R&D Employees Please Stand Up? Effects of Tax Breaks on Firm Level Outcomes, *International Tax and Public Finance*, vol. 24, 1-63.

Haegeland, T. and Moen, J. (2007), The Relationship Between the Norwegian R&D Tax Credit Scheme and other Innovation Policy Instruments, *Statistics Norway Reports*, No. 2007/ 45.

Hall, R. and Jorgenson, D. (1967), Tax Policy and Investment Behaviour, *The American Economic Review*, vol. 57(3), 391-414.

Hansson, A. and Brokelind, C. (2014), Tax Incentives, Tax Expenditures Theories in R&D: The Case of Sweden, *World Tax Journal*, vol. 6(2), 168-200.

Heritage Foundation (2017), Database *Index of Economic Freedom*, available at: http://www.heritage.org/index/

Jorgenson, D. (1963), Capital Theory and Investment Behaviour, *The American Economic Review*, vol. 53(2), 247-259.

Karkinsky, T. and Riedel, N. (2012), Corporate Taxation and the Choice of Patent Location within Multinational Firms, *Journal of International Economics*, vol. 88(1), 176-185.

Kasahara, H., Shimotsu, K., and Suzuki, M. (2014), Does an R&D Tax Credit Affect R&D Expenditure? The Japanese R&D Tax Credit Reform in 2003, *Journal of the Japanese and International Economics*, vol. 31, 72-97.

King, M. and Fullerton, D. (1984), *The Taxation of Income from Capital*, Chicago.

Klassen, K., Pittman, J., and Reed, M. (2004), A Cross-national Comparison of R&D Expenditure Decisions: Tax Incentives and Financial Constraints, *Contemporary Accounting Research*, vol. 21(3), 639-680.

Kobayashi, Y. (2014), Effect of R&D Tax Credits for SMEs in Japan: A Microeconometric Analysis Focused on Liquidity Constraints, *Small Business Economics*, vol. 42(2), 311-327.

Lee, C. (2011), The Differential Effects of Public R&D Support on Firm R&D: Theory and Evidence from Multi-Country Data, *Technovation,* vol. 31(5/6), 256-269.

Lokshin, B. and Mohnen, P. (2012), How Effective are Level-Based R&D Tax Credits? Evidence from the Netherlands, *Applied Economics*, vol. 44(12), 1527-1538.

Mankiw, N. and Taylor, M. (2014), *Macroeconomics*, Thomson, London.

Mulkay, B. and Mairesse, J. (2013), The R&D Tax Credit in France: Assessment and Ex Ante Evaluation of the 2008 Reform, *Oxford Economic Papers*.

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

OECD (2014), *A Study on R&D Tax Incentives: Final Report*, TAXUD/2013/DE/315, CPB Netherlands Bureau for Economic Policy Analysis, the Netherlands.

OECD (2015), *Action Plan on Base Erosion and Profit Shifting - Action 5: Agreement on Modified Nexus Approach for IP Regimes*, OECD publishing, Paris.

OECD (2016a), Database *Gross Domestic Expenditure on R-D by Sector of Performance and Source of Funds*, available at: http://stats.oecd.org/Index.aspx?DataSetCode=GERD_FUNDS

OECD (2016b), Database *International Co-Operation in Patents*, available at: https://stats.oecd.org/Index.aspx?DataSetCode=PATS_COOP

Piantavigna, P. (2017), Tax Abuse and Aggressive Tax Planning in the BEPS Era: How EU Law and the OECD Are Establishing a Unifying Conceptual Framework in International Tax Law, despite Linguistic Discrepancies, *World Tax Journal*, vol. 9(1), 47-98.

Schreiber, U., Spengel, C., and Lammersen, L. (2002), Measuring the Impact of Taxation on Investment and Financing Decisions, *Schmalenbach Business Review*, vol. 54(1), 2-23.

Solow, R. (1956), A Contribution to the Theory of Economic Growth, *The Quarterly Journal of Economics*, vol. 70(1), 65-94.

Spengel, C. (2016), IP-Box Regime und Steuerliche Förderung von Forschung und Entwicklung – Passt Das Zusammen? In: Lüdicke, J. (Ed.), *Besteuerung Internationaler Unternehmen : Festschrift für Dieter Endres zum 60. Geburtstag*, München, 409-423.

Spengel, C. and Elschner, C. (2010), Steuerliche Anreize für Forschung und Entwicklung – Empirische Befunde, Internationaler Vergleich und Reformansätze für Deutschland, *Zeitschrift für Betriebswirtschaft*, vol. 2, 1-22.

Spengel, C. and Lammersen, L. (2001), Methoden zur Messung und zum Vergleich von Internationalen Steuerbelastungen, *Steuer und Wirtschaft*, vol. 31(3), 222-238.

Spengel, C. and Wiegard, W. (2011), *Ökonomische Effekte einer Steuerlichen Forschungsförderung in Deutschland*, Studie im Auftrag des Bundesverbandes der Deutschen Industrie e.V. (BDI) und des Verbandes der Chemischen Industrie e.V. (VCI), Germany.

Thomson, R. (2013), Measures of R&D Tax Incentives for OECD Countries, *Review of Economics and Institutions*, vol. 4(3), 2-35.

Thomson, R. (2015), The Effectiveness of R&D Tax Credits, *The Review of Economics and Statistics*, vol. 8, 1-21.

Warda, J. (2001), Measuring the Value of R&D Tax Treatment in OECD Countries, *OECD STI Review*, vol. 27, 185-211.

Westerlund, J. and Wilhelmsson, F. (2011), Estimating the Gravity Model without Gravity Using Panel Data, *Applied Economics*, vol. 43(6), 641-649.

Westmore, B. (2013), R&D, Patenting and Growth: The Role of Public Policy, *OECD Economics Department Working Papers*, No. 1047.

Wilson, D. (2009), Beggar thy Neighbour? The In-State, Out-Of-State and Aggregate Effects of R&D Tax Credits, *The Review of Economics and Statistics*, vol. 91(2), 431-436.

Wooldridge, J. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge, MA, 127-128.

World Bank (2017), Database *World Bank Development Indicators*, available at: http://data.worldbank.org/data-catalog/world-development-indicators

Yang, C., Huang, C., and Hou, T. (2012), Tax Incentives and R&D Activity: Firm-Level Evidence from Taiwan, *Research Policy*, vol. 41(9), 1578-1588.

ZEW (2016), Final Report 2016: Effective Tax Levels Using the Devereux/Griffith Methodology, *Project for the EU Commission TAXUD/2013/CC/120*, Mannheim.

Appendix. Country Names and Abbreviations

Abbreviation	Country	Abbreviation	Country
AT	Austria	IE	Ireland
BE	Belgium	IS	Island
BG	Bulgaria	IT	Italy
CH	Switzerland	LI	Liechtenstein
CY	Cyprus	LT	Lithuania
CZ	Czech Republic	LU	Luxembourg
DE	Germany	LV	Latvia
DK	Denmark	MT	Malta
EE	Estonia	NL	Netherlands
ES	Spain	NO	Norway
FI	Finland	PL	Poland
FR	France	PT	Portugal
GB	United Kingdom	RO	Romania
GR	Greece	SE	Sweden
HR	Croatia	SI	Slovenia
HU	Hungary	SK	Slovakia