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Effects of Fiscal R&D Incentives on R&D Expenditure

Anna Theresa Bührle

Universität Mannheim

Abstract

Special tax incentives aiming to foster research and development (R&D) investment are widely spread among the members of the Organisation for Economic Co-operation and Development (OCED). I investigate the effect such tax incentives have on business R&D investment. Fiscal R&D incentives can be categorized as input-oriented tax incentives such as tax credits, super deductions and accelerated depreciation, and as output-oriented incentives such as patent box regimes. In the first part of my thesis I provide an overview over the methodology of the B-Index, a measure for the generosity of input-oriented tax incentives. Calculations of the B-Index for 33 OECD-countries and China from 1991 to 2014 show an overall trend towards an increase in the generosity of input-oriented fiscal R&D incentives. In the second part of my thesis, I create a panel with country-level data on business R&D investment provided by the OECD. I test reactions to changes in R&D tax incentives and find a positive effect of input-oriented R&D tax incentives, but no significant impact of output-oriented R&D tax incentives. A more detailed analysis on the industry-level shows that the results are driven by effects on business R&D investment in the manufacturing and services sector.

Keywords: R&D, tax incentives, B-Index, taxation, OECD

1. Introduction

Research and development (R&D) investment does not only create advantages for the investing companies, but also for the public through so-called technological spillovers.[1] However, empirical evidence shows that business R&D expenditure is below the social optimum. Reasons for that are externalities that influence the profitability of the R&D investment.[2] Therefore, to profit from the knowledge spillover effects, governments have an incentive to stimulate private R&D investment. While direct funding like government grants and subsidies decreased over the past few decades, the generosity of indirect support via fiscal R&D incentives increased.[3] More and more countries started to introduce input-oriented fiscal incentives to promote R&D investment. In recent years, output-oriented fiscal R&D incentives also grew in popularity.

This thesis serves two purposes. Firstly, it aims to make the data on R&D incentives and on the B-Indices, which measure the generosity of input-oriented R&D incentives, available for other researchers. Data on the total B-Index has been published by the OECD for individual years. Ernst and Spengel (2011) give an overview over R&D tax incentives and total B-Indices for 20 European countries between 1998 and 2007. Thomson (2013) presents background data and measures separated by type of cost for 26 OECD countries for the period 1980-2006. This thesis continues this work and provides the B-Indices for an extended country sample and updated period of time as well as all formulas and variables used for the calculations. In this first part, a qualitative analysis is conducted, investigating the development of fiscal R&D incentives. Secondly, this thesis also extends the existing empirical research on the effectiveness of the tax measures. The quantitative analysis executed in the second part uses empirical methods and includes a cross-country study on the effect of fiscal R&D incentives on R&D investment in different industries. Existing empirical studies mainly investigate the effect of the introduction of fiscal R&D incentives within one country; studies that include several countries, observation years and types of tax incentives are rare.[4]

The structure is as follows. Chapter 2 gives an overview over the main types of fiscal input- as well as output-oriented R&D incentives. In addition, the B-Index as a measure for the

[1] See e.g. Griliches (1992), pp. 43-44.
[2] See e.g. Nelson (1959), p. 304, Arrow (1962), pp. 616-619.
[3] See Westmore (2013), p. 11.
[4] Please refer to chapter 4.1 for examples of cross-country studies.

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generosity of input-oriented R&D incentives is introduced. In chapter 3, the existing fiscal R&D incentives for 33 OECD countries and China for the period from 1991 to 2014 are displayed and qualitatively analyzed. Chapter 4 gives a brief review on previous studies on the effects of the B-Index on R&D investment. This is followed by the introduction of data used in the quantitative analysis and the results of the empirical study. The last chapter concludes.

2. Fiscal R&D incentive models: Basic concepts

2.1. Input-oriented R&D tax incentives

Legislators use different ways to implement tax incentives to promote R&D. Input- oriented incentives target a company's R&D investment and reduce the marginal costs of the R&D projects. They take the form of tax credits, super deductions (also referred to as enhanced or extra allowances) or accelerated depreciation. As of 2014, 29 of the 34 countries included in this thesis provide at least one of those incentive schemes.[5]

Tax credits reduce a company's tax liability. A predefined percentage of the R&D expenditure incurred can be directly offset against the tax due. Super deductions and accelerated depreciation on the other hand reduce a company's tax base. In case of the super deduction, an enhanced allowance on top of the usually deductible amount of expenditure can be claimed. Under this scheme, e.g. in the Czech Republic the tax base can be reduced by up to double of the amount of costs incurred. With accelerated depreciation, the depreciation rates for fixed R&D assets are enhanced. The capitalized expenditure can be deducted faster, which leads to a lower tax base in the affected periods.[6]

A special form of fiscal R&D incentive applies to the wage withholding tax for R&D personnel. The wage withholding tax payable by the employer is lowered. The company still withholds the full tax amount from its employees wage payments, but pays only a fraction to the state. As a result, the R&D labor costs for the company are reduced.[7]

The R&D tax incentives mentioned above are calculated based either on current costs, or on capital expenditure, or both. Current costs include labor expenditure and other current costs, such as expenditure on consumable material. Capital expenditure is composed of expenditure on machinery and equipment and expenditure on buildings. Some countries do not allow for the expenditure to be included at once. Instead, they only allow to add the depreciation costs to the basis. In general, acquisition cost for land is not allowed to be included in the basis for any of the observed tax incentive schemes.

Another feature of the tax incentives is their link to either the volume or the increment of R&D expenditure. In case of a scheme based on volume, the incentive applies to the total amount of R&D expenditure incurred by a company. In contrast, incremental schemes aim at increases of the company's R&D expenditure. If an incremental scheme is applied, companies can only profit from a tax reduction if the expenditure in the current period exceeds a base amount. The definition of this base amount differs from scheme to scheme. E.g. Ireland allows a tax credit for R&D expenditure exceeding the R&D expenditure of the company in the fixed base year 2003. Other countries like Australia, Greece and Japan calculate a moving average of the R&D expenditure of up to five previous years. At times, the USA offered three mutually exclusive credit regimes, each with its own definition for the relevant base amount.[8]

Part of the fiscal R&D incentives are also limited by floors and/or caps. In the first case, tax relief is only granted if the R&D expenditure exceeds a certain value (e.g. for the Finnish super deduction EUR 15,000). In the second case, fiscal R&D incentives are capped at a certain value (e.g. for the Italian tax credit in 2010 EUR 50 million) or limited by a percentage of the tax liability (e.g. for the Japanese tax credit from 1991 to 1998 10% of tax due before the credit).

Some of the R&D tax incentives differentiate depending on firm size; e.g. smaller companies benefit from more generous rates or the scheme is limited to enterprises that meet certain employment or turnover criteria.

2.2. B-Index: Definition and methodology

To calculate the generosity of input-oriented R&D tax incentives, the OECD[9] calculates tax subsidy rates based on the benefit cost ratio at which an R&D investment opportunity becomes viable after tax (B-Index).[10] Several studies also rely on the B-Index as a measure for R&D tax support.[11] The measure represents the tax component of the user cost of capital which was introduced by Jorgenson (1963). McFetridge and Warda (1983) adapted the user cost of capital to R&D investment and introduced the B-Index model. As a marginal concept, the B-Index is an indicator for marginal investment decisions, e.g. the scope of an investment (as opposed to discrete investment decisions, e.g. a corporation's location decision).[12]

The B-Index model is limited to the corporate income tax regime, i.e. personal income taxes and several other taxes that might apply as well as grants and subsidies are disregarded. It is also assumed that the companies generate sufficient taxable income to fully utilize the R&D tax incentives in the current year (no tax exhaustion); therefore carry-forward

[5] Germany, Mexico and New Zealand currently do not have or revoked previously existing input- oriented tax incentive schemes. Denmark and Poland offer restricted R&D incentives that are only applicable to a limited range of companies fulfilling certain conditions.

[6] See CPB et al. (2014), p. 50.

[7] See Ernst and Spengel (2011), p. 8.

[8] See Taxand (2009), pp. 29-32 for a short overview over the three schemes.

[9] See OECD (2017).

[10] See Warda (2001), p. 192.

[11] See e.g. Falk (2006), Corchuelo and Martínez-Ros (2010), Ernst and Spengel (2011), Westmore (2013), Bösenberg and Egger (2017).

[12] See Bösenberg and Egger (2017), p. 43.

or carry-back provisions do not apply. In addition, the corporate income tax rates and incentives applicable to the top eligible income are considered. Ceilings and floors that limit the claim on R&D tax incentives are disregarded for reasons of simplicity.[13]

The measure is calculated as the net present value (NPV) of income which covers the initial R&D investment and taxes:[14]

$$b = \frac{1-A}{1-\tau} \tag{1}$$

with $\tau =$ corporate income tax rate

$A =$ NPV of all R&D incentives applicable

A consists of the sum of the individual NPVs (A_n) of four types of R&D costs: current costs which are sub-divided into labor (A_L) and other current costs (A_{OC}) and capital expenditure which is sub-divided into machinery and equipment (A_{ME}) and buildings (A_B):

$$A = \sum w_n * A_n = W_L * A_L + w_{OC} * A_{OC} + w_{ME} * A_{ME} + w_B * A_B \tag{2}$$

with $w_n =$ weight attributed to expenditure type n

$w_L =$ weight attributed to labor costs

$w_{OC} =$ weight attributed to other current costs

$w_{ME} =$ weight attributed to machinery and equipment costs

$w_B =$ weight attributed to costs for buildings

Each A_n is a combination of the NPVs of the depreciation of the expenditure as well as the NPVs of the tax credits, super deductions and reductions of wage withholding tax that are available in addition:

$$A_n = d_d^n * a_d^n + d_{tc}^n * a_{tc}^n + d_{sd}^n * a_{sd}^n + d_{wwt}^n * a_{wwt}^n \tag{3}$$

with $d_d^n =$ weight attributed to expenditure type n

$d_d^n =$ value of expenditure subject to depreciation in t=0

$d_{tc} =$ value of expenditure subject to tax credit in t=0

$d_{sd} =$ value of expenditure subject to super deduction in t=0

$d_{wwt}^n =$ value of expenditure subject to wage withholding tax tax reduction in t=0

$a_d^n =$ NPV depreciation

$a_{tc}^n =$ NPV tax credit

$a_{sd}^n =$ NPV super deduction

$a_{wwt}^n =$ NPV wage withholding tax reduction

The value of d equals 1 if the tax incentive is calculated based on the full amount of the expenditure. In case of R&D expenditure on machinery and equipment or buildings, R&D tax incentives can be calculated based on the amount of the depreciation instead. Then, d is calculated as follows:

$$d_d^{SL} = \frac{1}{T} * [1 - (\frac{1}{1+r})^T] * \frac{1+r}{r} \tag{4}$$

$$d_d^{DB} = d * \frac{(1+r)}{d+r} \tag{5}$$

with $d_d^{SL} =$ d, if the basis is the depreciation of assets with a straight-line schedule

$d_d^{DB} =$ d, if the basis is the depreciation of assets with a declining-balance schedule

$r =$ discount rate

$T =$ useful life of asset

The respective values for the NPVs of the depreciation and input-oriented tax incentives are each calculated based on the individual regulations in place.

The NPV of the depreciation, a_d^n, equals 1 if the expenditure can be immediately deducted (which applies to the majority of countries for current costs[15]). If the R&D expenditure has to be capitalized, the straight-line or the declining-balance method are possible. The formulas assume that assets are depreciated at the beginning of the period.

$$a_d^{SL} = \frac{1}{T} * [1 - (\frac{1}{1+r})^T] * \frac{1+r}{r} * \tau \tag{6}$$

$$a_d^{DB} = d * \frac{(1+r)}{d+r} * \tau \tag{7}$$

with $a_d^{SL} =$ NPV straight-line depreciation

$a_d^{DB} =$ NPV declining-balance depreciation

Tax credits are either granted before taxes, and therefore subject to corporate taxation (e.g. Canada), or after taxes (e.g. Austria):

$$a_{tc}^{non-tax} = tc \tag{8}$$

$$a_{tc}^{tax} = tc * (1-\tau) \tag{9}$$

[13] See Warda (2001), p. 193-194.

[14] See Warda (2001), p. 192.

[15] Only in a few countries research and/or development costs cannot be immediately expensed. For example in the Czech Republic, Ireland, Poland or Portugal the capitalization of R&D expenditure is mandatory if certain conditions are fulfilled. In the Netherlands, Slovak Republic only development expenditure is subject to mandatory capitalization. Other countries like Greece, Italy and Luxembourg allow an option, while R&D costs are regarded as non-capitalisable in Austria and Germany. See Endres et al. (2007), pp. 291-295.

with $a_{tc}^{non-tax}$ = NPV non-taxable tax credit

a_{tc}^{tax} = NPV taxable tax credit

tc = tax credit rate

The super deduction directly reduces the taxable income:[16]

$$a_{sd} = sd * \tau \tag{10}$$

with sd = super deduction rate

If the tax credit or super deduction is based on an incremental scheme with a k-period moving average as a base for the increase in R&D expenditure, the respective NPVs are multiplied by the following:[17]

$$1 - \frac{1}{k}\sum_{k=1}^{K}(1+r)^{-k} \tag{11}$$

with K = number of periods used for calculation of average

In case of the reduction of the wage withholding tax, the rate does not reduce the payment of corporate income taxes, but wage withholding taxes instead:

$$a_{wwt} = wwt * \tau_{wwt} \tag{12}$$

with wwt = reduction rate wage withholding tax

τ_{wwt} = wage withholding tax rate

The preceding formulas rest on the assumption that the investment is financed by retained earnings.[18]

2.3. Output-oriented R&D tax incentives

In contrast to the types of R&D tax incentives discussed in the preceding paragraph, states also aim to foster innovation by influencing the taxation of the output of R&D processes. From 1973 until 2010, Ireland exempted patent royalty income for domestic R&D.[19] As of 2014, 8 out of the 34 countries considered in this thesis offer a so-called intellectual property (IP) box[20] that provides a reduced tax rate on the income generated through the exploitation of successful innovations in the form of patents.[21] Other research activity which cannot be patented but may generate higher spillover effects is not rewarded.[22] The national regimes differ with respect to qualifying IP and income as well as the treatment of past and current R&D expenditure. The application of IP boxes can lead to a substantial reduction of the cost of capital of the R&D investment, therefore making it more favorable than a comparable financial investment. [23]

Empirical evidence suggests that output-oriented R&D incentives impact the number and location of patents rather than the amount of R&D expenditure.[24] Until today, an effect on R&D investment could not be empirically confirmed.[25] Therefore, IP boxes and their specific design will not be addressed in detail in this thesis.

3. Fiscal R&D incentive schemes in the OECD

3.1. Overview over existing input- and output-oriented R&D incentives

This chapter presents an overview over existing systems and a qualitative analysis across countries and time. Within the OECD, a magnitude of fiscal R&D incentives are in place. Table 1 and Table 2 give an overview over the input- respective output-oriented R&D incentives that are or were available from 1991-2014 in 33 OECD countries and China. For the purpose of this thesis, only incentives that are available to all firms are included. Incentives aimed solely on SMEs are not considered, and in case of different rates the top rates are applied. Floors and caps are disregarded.

The information displayed in Table 1 originates from various sources. The major part was derived from the IBFD (1991-2004) and the IBFD Country Analyses. The data was completed and verified with research results from Ernst and Spengel (2011) and Thomson (2013) as well as with the global guides from the OECD (OECD (2013), OECD (2015)), EY (EY (2010),EY (2013), EY (2014)), PwC (PwC (2012), PwC (2014), PwC (2016)), Deloitte (Deloitte (2011), Deloitte (2012), Deloitte (2014)), Taxand (Taxand (2009), Taxand (2011)) and various national sources.

In the column "Capitalization of R&D expenditure" only countries are shown were research as well as development expenditure are subject to mandatory capitalization without further requirements like e.g. special cost documentation. In the columns "Tax Credit" and "Super Deduction", italic and bracketed crosses represent the less favorable scheme if a country offers several mutually exclusive R&D tax incentives. A more detailed version of Table 1 can be found in the appendix (Table A - 1).

In 1991, 17 out of 34 countries had input-oriented incentive schemes implemented. Six countries offered tax credits, three super deduction and eleven accelerated depreciation. In 2014, in 29 out of 34 countries fiscal R&D incentives are available. The number of countries offering tax credits (now

[16] In 2006, Belgium introduced a notional interest deduction (NID) regime. The NID rates are included in the B-Index similarly to the calculation of a super deduction.

[17] See Bloom et al. (2002), p. 5, Thomson (2013), p. 4.

[18] See Ernst and Spengel (2011), p. 18.

[19] See IBFD (1991-2004), IBFD (2005-2014).

[20] Comparable regimes are also referred to as patent, innovation or knowledge development box.

[21] See IBFD (1991-2004), IBFD (2005-2014).

[22] See Alstadsæter et al. (2015) p. 3.

[23] See Evers et al. (2015), p. 514.

[24] See e.g. Karkinsky and Riedel (2012), Griffith et al. (2014), Bradley/Dauchy/Robinson (2015).

[25] See also De Rassenfosse (2015), p. 15, Alstadsæter et al. (2015), pp. 2-3.

Table 1: Input-oriented R&D incentives in the OECD, 1991-2014; Source: IBFD (1991-2004), IBFD (2005-2014), Thomson (2013), Ernst and Spengel (2011), own research.

(1) For Canada and Switzerland only incentives on the state level are taken into account. On the provincial/cantonal level, additional incentives exist.
(2) Estonia introduced a distribution tax system in 2000. For the purposes of the calculations, immediate distribution (and therefore taxation) of profits was assumed. Depreciation of machinery and equipment as well as buildings was modeled as a 100% write-off in the first year.

Country	Year	Capitalisation of R&D exp.	Tax Credit		Super Deduction		Acc. Depr.	Reduction WWT
			Vol.	Incr.	Vol.	Incr.		
AT	1991-1999				x			
	2000-2005				x	x		
	2006-2010		x		(x)	(x)		
	2011-2014		x					
AU	1991-1995				x		x	
	1996-2000				x			
	2001-2011				x	x		
	2012-2014		x					
BE	1991-2005				x		x	
	2006				x		x	x
BE	2007-2014		(x)		x		x	x
CA(1)	1991-2013		x				x	
	2014		x					
CH(1)	1991-2014							
CL	2013-2014		x				x	
CN	2008-2014				x			
CZ	2005-2013				x			
	2014				x	x		
DE	1991-2014							
DK	1991	10 yrs					x	
	1992-1997						x	
EE	1993-1999	5 yrs						
	2000-2014						x(2)	
ES	1991-2014		x	x			x	
FI	1991-2012						x	
	2013-2014				x		x	
FR	1991-2003			x				
	2004-2007		x	x				
	2008-2014		x					
GB	1991-2001						x	
	2002-2012				x		x	
	2013-2014		x		(x)		x	
GR	1991-2004						x	
	2005-2012					x	x	
	2013-2014				x		x	
HU	1991-1996						x	
	1997-2004				x		x	
	2005-2011		x		x		x	
	2012-2014				x		x	

(Continued)

Table 1—continued

Country	Year	Capitalisation of R&D exp.	Tax Credit Vol.	Tax Credit Incr.	Super Deduction Vol.	Super Deduction Incr.	Acc. Depr.	Reduction WWT
IE	1991-2003						x	
	2004-2014		x	x			x	
IL	1994-2014						x	
IS	2011-2014		x					
IT	2007-2009		x					
	2010		x		x			
	2011-2014		x					
JP	1991-2002			x				
JP	2003-2014		x	(x)				
KR	1991-1997		x	x				
	1998-2014		(x)	x				
LU	1998-2014						x	
MX	1991-1996						x	
	1997-2001			x			x	
	2002-2009		x				x	
NL	1991-1993	5 yrs						
	1994-2006	5 yrs						x
	2007-2011							x
	2012-2014				x			x
NO	2003-2014		x					
NZ	2009		x					
PL	1991-2014							
PT	1997-2003		x	x				
	2005-2014		x	x				
SE	1991-2014							
SI	1994-2001						x	
	2006-2008				x			
	2009-2014				x		x	
SK	1991-2014							
US	1991-2014			x				

16 countries) and super deductions (now nine countries) increased considerably while the amount of accelerated depreciation remained nearly the same (now twelve countries). Two countries also implemented an incentive targeting wage withholding taxes (Belgium and the Netherlands). Only five out of the 34 countries observed (Switzerland[26], Germany, Poland, Sweden and the Slovak Republic) never offered any kind of input-oriented R&D incentive.

In most countries, R&D tax incentives were subject to several adjustments over the observed period of time. In Belgium, Spain and Korea the rate and basis applicable were changed up to eight times since the introduction of the respective schemes. Canada, Finland, France, Ireland, Norway and the USA on the other hand show more stability in their R&D incentive tax system. In those countries the input-oriented incentive schemes lasted more than ten years before changes were made.

In general, fiscal R&D incentives grew more popular over the years. Regarding the design and continuity of the input-oriented R&D incentive schemes a great variety can be observed in the sample.

The data on IP box regimes in Table 2 was mainly compiled from the IBFD country analyses and Evers et al. (2015).

[26] For Canada and Switzerland only incentives on the state level are taken into account. On the provincial/ cantonal level, additional incentives exist.

Table 2: Output-oriented R&D incentives in the OECD, 1991-2014; Source: IBFD (1991-2004), IBFD (2005-2014), Evers et al. (2015), own research.

Country	Year	Incentive
BE	2007-2014	80% reduction of tax base
ES	2008-2014	60% reduction of tax base
FR	2000-2010 2011-2014	15.495% tax rate 16.245% tax rate
HU	2003-2014	50% reduction of tax base
IE	1973-2010	0% tax rate
LU	2008-2014	80% reduction of tax base
NL	2007-2009	10% tax rate
	2010-2014	5% tax rate
PT	2014	50% reduction of tax base
GB	2013-2014	10% tax rate

The introduction of output-oriented R&D incentives mainly started post-millennial; the systems grew in popularity over the years. As of 2014, eight of 34 countries offer regimes with significantly reduced tax rates or a reduction of the tax base for eligible intellectual property income. Ireland stands out as the only country which discontinued its system where eligible income was fully tax exempt; it was in place from 1973 until 2010.

3.2. Overview of B-Index

As already mentioned in chapter 2.2, the B-Index serves as a quantitative measure of the generosity of the R&D tax incentive system of a country. Table 3 shows the values of the B-Indices for all the years and countries considered in this thesis[27]

The B-Index is calculated based on the formulas listed in chapter 2.2 and the data on input-oriented R&D incentives displayed in Table 1.[28] The discount rate is held fixed at 10% across all countries and years.[29] The cost types are weighted with w_L=0.6, w_{OC}=0.3 , w_{ME}=0.05 and w_B=0.05. This standard is commonly used for the calculation of the B-Index[30] and is a simplification of the weights determined in industrial surveys.[31] It is assumed that the R&D investments are conducted in-house in the resident country of the corporations. R&D incentives available on a sub-national level[32] or subject to size limits, i.e. fiscal incentives aimed at SMEs, are not modeled. As for the depreciation schedules, if no specific rules apply straight-line depreciation with a useful life of 7 years for machinery and equipment and 40 years for buildings was assumed.

3.3. Qualitative analysis

As the B-Index measures the generosity of a country's R&D tax system, it reflects the changes in the input-oriented R&D incentives, depreciation rules and tax rates. A B-Index of 1 implies that a corporation has to generate 1 unit of before-tax income to break even for the additional investment. For values greater than 1, companies have to earn more income than the 1 unit invested to compensate for the tax burden. If the B-Index lies below 1, the favorable tax treatment leads to a situation where a corporation has to earn less than the initial investment to break even.[33] E.g. in 2003, a German company would have had to earn EUR 1.03 million to offset an additional R&D investment of EUR 1 million while an Austrian company only would have had to generate EUR 0.88 million to break even.

In Figure 1, the mean values of the B-Indices, differentiated by the four cost types (machinery and equipment (ME), buildings (B), labor (L), other current costs (OC)) are displayed.[34] The B-Indices concentrate on the fiscal R&D incentives relevant for the respective cost type, as the majority of incentive schemes do not apply to all R&D expenditure incurred by a company.

Overall, the B-Indices drop considerably over time. The total mean value decreases by 0.15 from 0.99 in 1991 to 0.84 in 2014.

The mean B-Indices for buildings show substantially higher values compared to every other cost type. For buildings, the mean amounts to 1.35 in 1991 while the mean for

[27] Table A - 4 in the appendix shows the components of the B-Index attributable to the separate expenditure types.

[28] A more detailed version of Table 1 is displayed in the appendix (Table A - 1). Please also refer to the appendix for the depreciation schedules (Table A - 2) and the corporate income tax rates (Table A - 3) used for the calculation.

[29] This is consistent with Warda (2001), p.193 and Thomson (2013), p. 5.This is consistent with Warda (2001), p.193 and Thomson (2013), p. 5.

[30] See e.g. Warda (2001), p. 189, Ernst and Spengel (2011), p. 29, Thomson (2013), p. 4.

[31] See e.g. Cameron (1996), p. 216.

[32] This is relevant in the case of Canada and Switzerland, where some of the states respective cantons provide fiscal R&D incentives in addition to incentive schemes on the national level.

[33] See Warda (2001), p. 190.

[34] For the underlying values, please refer to Table 3 in the preceding chapter and Table A - 4 in the appendix.

Table 3: Total B-Indices in the OECD, 1991-2014; Source: Own calculations.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AT	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.88	0.88	0.88
AU	0.72	0.72	0.79	0.79	0.76	0.76	0.89	0.89	0.89	0.90	0.87	0.87
BE	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
CA	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.83	0.83
CH	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
CL										1.01	1.01	1.01
CN											1.02	1.02
CZ			1.04	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02
DE	1.05	1.05	1.05	1.04	1.04	1.05	1.05	1.05	1.04	1.04	1.03	1.03
DK	1.18	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.02	1.02	1.02	1.02
EE			1.10	1.06	1.06	1.06	1.06	1.06	1.06	1.00	1.00	1.00
ES	0.70	0.70	0.70	0.70	0.70	0.65	0.65	0.65	0.65	0.48	0.69	0.69
FI	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
FR	0.91	0.92	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.92	0.92	0.92
GB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90
GR	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.01	1.01
HU	1.03	1.03	1.03	1.02	1.01	1.01	0.97	0.97	0.97	0.81	0.81	0.81
IE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IL				1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00
IS	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01
IT	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.03	1.03	1.03	1.03	1.03
JP	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	0.98	0.98	0.98
KR	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.88	0.88	0.88	0.88	0.88
LU	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.01
MX	1.02	1.02	1.02	1.02	1.02	1.02	0.97	0.97	0.97	0.97	0.97	0.55
NL	1.10	1.10	1.10	1.04	1.04	1.04	1.04	1.01	1.03	1.03	1.04	1.04
NO	1.04	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
NZ	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
PL	1.04	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02
PT	1.02	1.02	1.02	1.02	1.02	1.02	0.83	0.83	0.83	0.84	0.65	0.66
SE	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SI				1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
SK			1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02
US	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
AT	0.88	0.88	0.92	0.92	0.92	0.92	0.92	0.92	0.88	0.88	0.88	0.88
AU	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.48	0.48	0.48
BE	1.01	1.01	1.01	0.75	0.74	0.74	0.62	0.62	0.62	0.62	0.60	0.60
CA	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.82	0.82	0.82	0.88

(Continued)

Table 3—continued

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CH	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
CL	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.65	0.66
CN	1.02	1.02	1.02	1.02	1.02	0.84	0.84	0.84	0.84	0.84	0.84	0.84
CZ	1.02	1.02	0.68	0.72	0.72	0.76	0.78	0.79	0.79	0.79	0.79	0.77
DE	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02
DK	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
EE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ES	0.69	0.60	0.60	0.60	0.64	0.68	0.68	0.68	0.68	0.68	0.68	0.68
FI	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.81	0.86
FR	0.92	0.85	0.85	0.79	0.79	0.94	0.94	0.94	0.94	0.94	0.94	0.94
GB	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.91	0.91	0.91	0.91
GR	1.01	1.01	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.64	0.64
HU	0.81	0.84	0.77	0.75	0.71	0.71	0.71	0.72	0.72	0.80	0.80	0.80
IE	1.00	0.97	0.95	0.94	0.92	0.91	0.90	0.85	0.84	0.83	0.82	0.81
IL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IS	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.76	0.76	0.76	0.76
IT	1.03	1.03	1.03	1.03	0.87	0.87	0.87	0.87	0.87	0.71	0.71	0.71
JP	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
KR	0.91	0.91	0.91	0.91	0.91	0.83	0.77	0.91	0.91	0.91	0.91	0.91
LU	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
MX	0.56	0.57	0.58	0.59	0.60	0.60	0.60	0.58	0.58	0.58	0.58	0.58
NL	1.04	1.04	1.03	1.02	0.96	0.96	0.96	0.96	0.94	0.90	0.88	0.88
NO	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
NZ	1.02	1.02	1.02	1.02	1.02	1.02	0.82	1.02	1.02	1.02	1.02	1.02
PL	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
PT	0.66	1.01	0.66	0.66	0.67	0.67	0.67	0.51	0.49	0.47	0.47	0.47
SE	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01
SI	1.01	1.01	1.01	0.95	0.96	0.96	0.96	0.96	0.96	0.80	0.81	0.81
SK	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
US	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

machinery and equipment amounts to 1.05 at the same point in time. The main reason for this are the unfavorable depreciation rules for buildings, as the majority of countries limits the annual depreciation to a depreciation time over ten to 50 years. Only six out of 34 countries grant accelerated depreciation for buildings at some point in time. Here the applicable useful life varies between five years or immediate deduction. Because the B-Index formula also relies on the concept of the time value of money, depreciation expenditure is worth more the sooner it is deductible from the tax base. Therefore, the longer the government sets the period of time over which the invested amount has to be depreciated, the higher the resulting B-Index (and the more expensive the investment) gets. In general, the useful life of buildings determined for tax purposes decreased over the years. This results in declining B-Indices. In addition, only twelve out of 34 countries grant input-oriented fiscal R&D incentive schemes that apply to the full expenditure or the depreciation on buildings. Eight of those countries introduced their regimes after 2001, leading to a further decline in the mean value of the B-Index for buildings. Overall, the B-Index drops from 1.35 in 1991 to 1.15 in 2014.

For machinery and equipment, the R&D incentive regimes are more favorable. 15 out of 34 countries allow for depreciation over three years up to immediate deduction, as opposed to normal schedules with a useful life between three to 20 years. Here, input-oriented R&D incentives are available in 21 out of 34 countries. The majority of the regimes (15 of 21)

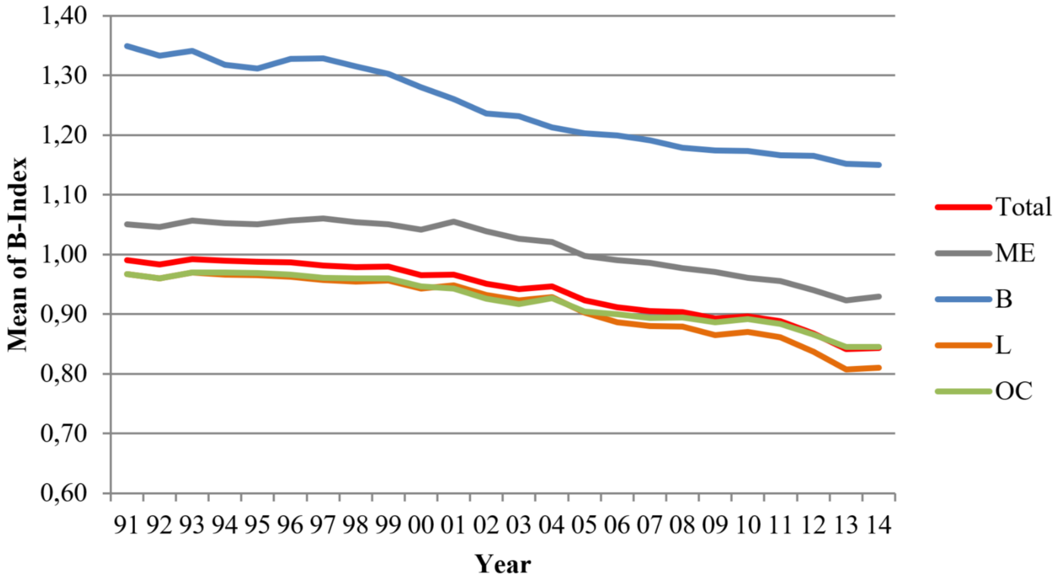

Figure 1: Development of B-Indices by cost type in the OECD, 1991-2014; Source: Own presentation.

was introduced after 2001, resulting in a decreasing mean B-Index in the subsequent years. In 2014, the mean B-Index for machinery and equipment amounts to 0.93 compared to 1.05 in 1991.

Considered over the whole time period, the mean B-Indices for labor and other current costs are always located below the 1.00-line. Only three countries require mandatory capitalization for R&D costs in the earlier years of the sample; from 2007 onwards this expenditure can be immediately deducted.[35] With 25 out of 34 countries offering fiscal R&D incentives, the majority of the regimes do not differentiate between labor and other current costs but do apply to current costs in general. However, in particular since 2006 the two curves disentangle. In 2005, the mean B-Indices for labor and other current costs are equal, nine years later the mean B-Index for labor amounts to 0.04 less than the mean B-Index for other current costs. The main reason for this development are the introduction of the wage withholding tax reduction in Belgium in 2006, the limitation of the Italian tax credit to R&D wages in 2012 and the introduction of the super deduction for R&D wages in Finland from 2013 onwards. Altogether, the B-Indices follow the trend of declining values with a B-Index for current costs of 0.97 in 1991 and B-Indices for labor and other current costs of 0.81 and 0.85 in 2014.

Figure 2 shows the development of the total B-Indices of the sample considered in this thesis.[36] Although it is difficult to differentiate the development of the B-Index of an individual country in the graph, Figure 2 gives an impression of the diversity of input-oriented fiscal R&D tax incentives across time as well as across countries. The volatility of the B-Indices reflects the variety of the underlying R&D tax regimes.

Only ten out of 34 countries remain in the area with a B-Index equal to or above 1. The five countries that do not offer any fiscal R&D incentives (Switzerland, Germany, Poland, Sweden and the Slovak Republic) account for half. Denmark, Estonia, Israel and Luxembourg offer accelerated depreciation schedules for R&D assets which reduce the B-Index down to 1 if the assets can be immediately depreciated. As there are no other input-related R&D incentives available, the respective B-Indices do not drop below the 1.00-line. In the case of the US a tax credit is available for the full period of time, but according to the calculations this tax advantage does not fully compensate for the disadvantages of the applicable depreciation schedules. If the ten countries in the top are excluded, the mean value of the total B-Index descends sharply by 0.2 from 0.97 in 1991 (compared to 0.99) to 0.77 in 2014 (compared to 0.84).

In all the other countries offering tax credits, super deductions or wage withholding tax reductions corporations benefit from a favorable tax treatment where the break-even point lies below the initial investment of 1. Depending on the generosity of the fiscal R&D incentive schemes, the B-Indices range between 0.97 and 0.47.

In the following, selected countries will be considered more in detail. Figure 3 depicts the development of the total B-Index in Portugal, Australia and France.

The graph clearly reflects the tax policy changes in Portugal over the years. Depreciation schedules remain constant over the whole period. In 1997, the tax rate was reduced from 39.6% to 37.4%. In addition, a new tax credit scheme was introduced with a volume credit of 8% and an incremental credit of 30% on current costs. This lead to a drop in the B-Index from 1.02 to 0.83. Subsequent reductions in

[35] Please refer to chapter 2.2, footnote 15 for further information about the capitalization of R&D expenditure and the assumptions made in this thesis.

[36] For the underlying values, please refer to Table 3 in the preceding chapter.

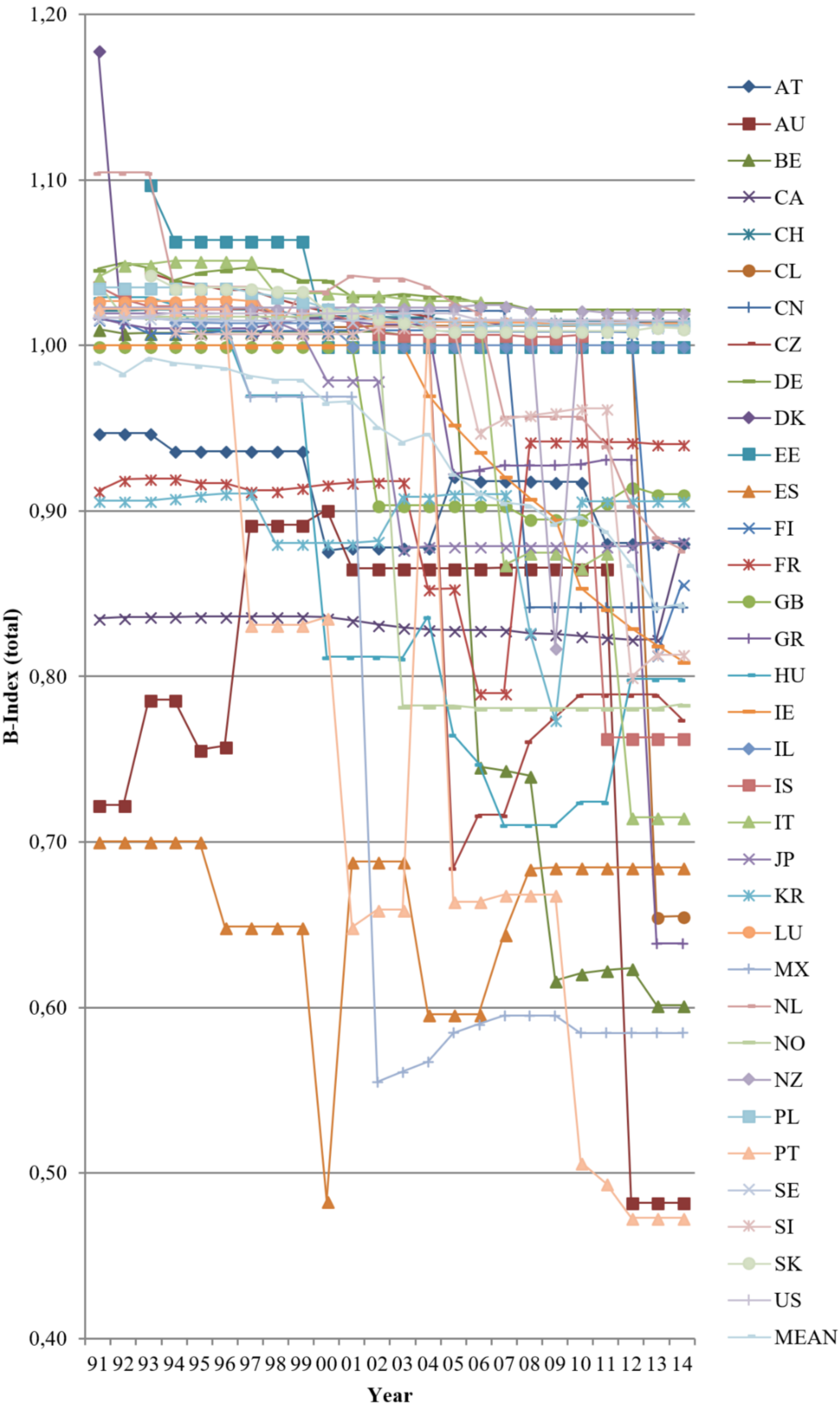

Figure 2: Development of B-Indices (total) in the OECD, 1991-2014; Source: Own presentation.

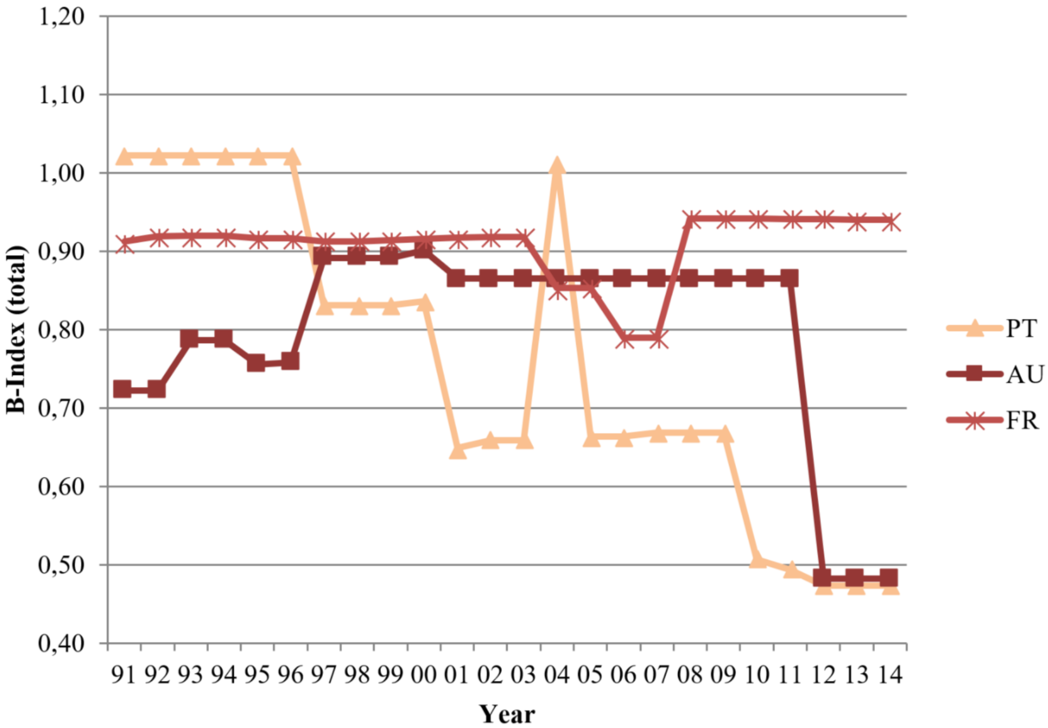

Figure 3: Development of B-Indices (total) in selected countries, 1991-2014; Source: Own presentation.

the corporate income tax rate to 35.2% in 2000 resulted in a slight increase to 0.84. In 2001, the tax credit rates were increased to 20% and 50%, resulting in a B-Index of 0.65. Further reductions of the corporate income tax rate to 33% in 2002 slightly increased the B-Index to 0.66. A high peak in 2004 (B-Index: 1.01) marks the reduction of the tax rate to 27.5%. and the abolishment of the tax credit regime. A similar scheme, now expanded to expenditure on machinery and equipment, reduced the B-Index again to the former level at 0.66. In 2007, the tax rate further decreased to 26.5% (B-Index: 0.67). In the following years, increases in corporate income tax rates (from 28.5% in 2011 to 31.5% from 2012 onwards) and tax credit rates (32.5% and 50% in 2010) let the B-Index decline to a value of 0.47 for 2012 to 2014. This makes the Portuguese tax credit in its form from 2012 onwards the most generous fiscal R&D incentive regime in all countries and years considered in this thesis.

Over the time period observed, the depreciation rates for machinery and equipment in Australia were subject to small changes in 1996 and 2007, which had no considerable effect on the B-Index. This is due to the assumed cost structure, as depreciation of machinery and equipment and depreciation of buildings only account for 5% each in the B-Index formula. From 1991 to 1997, Australia had a volume incentive scheme in place with a super deduction of 50% on current costs and the expenditure on machinery and equipment. Tax rate changes in 1993 (from 39% to 33%) and 1995 (from 33% to 36%) caused variations in the B-Index from 0.72 to 0.79 to 0.76. In 1997, the super deduction rate was cut in half to 25%, resulting in a jump in the B-Index by 0.13 to 0.89. A tax rate reduction in 2000 from 36% to 34% further increased the value to 0.9. The tax rate was again reduced in 2001 to 30%, but at the same time a 75% incremental regime was added to the super deduction, overcompensating for the tax rate change and setting the B-Index to 0.87. The B-Indices remained stable over the following years, until in 2012 the super deduction regime was abandoned and a tax credit scheme was introduced. The 40% tax credit resulted in a reduction of the B-Index down to 0.48.

In other countries where a super deduction regime was replaced by a tax credit scheme (Austria in 2006, Belgium in 2007, United Kingdom in 2013) the B-Index stayed constant or increased slightly. Therefore the substantial reduction in the Australian case cannot be generalized. Whether or not a super deduction regime is more or less favorable than a tax credit regime always depends on the design of the regimes before and after the change with regards to basis, rate and additional factors like the tax rates.

At first sight, France differs from all other countries in the sample. It is the only country where the development of the B-Indices shows a slight upwards trend, as displayed in Figure 3. The figure indicates three major changes. From 1991 to 2003, France applied an incremental tax credit regime with a 50% rate for current costs and the depreciation on machinery and equipment and buildings. In 2004, the tax credit was divided into a volume part of 5% and an incremental part of 45%, leading to a drop in the B-Index from 0.92 to 0.85. The tax credit rate change from 5% to 10% and 45% to 40% in 2006 further decreased the B-Index to 0.79. In 2008, an exclusively volume-based scheme was introduced. Under the new regime, companies can claim a 30% tax credit for expenditure up to EUR 100 million, above this threshold a 5% tax credit is available. Due to the assumptions made when calculating the B-Indices, the 5% rate is applied here,[37] thus leading to an increased B-Index of 0.94. If the 30% rate were applied, the value of the B-Index from 2008 to 2014 would amount to 0.55, thus following the overall downwards trend throughout the sample.

As can be seen from the precedent examples, changes in the tax rate have a small impact on the B-Index. Decreasing tax rates lead to slightly increasing B-Indices and vice versa. A possible explanation could be that the value of the output-oriented fiscal R&D incentives decreases with decreasing tax rates. For example in case of a double deduction, at a 40% tax rate a company saves 40 cents on every dollar invested. If the tax rate is reduced to 30%, the tax savings drop to 30 cents on every dollar invested. Alterations regarding the tax incentive regimes tend to have a much bigger influence, depending on the size of the changes. To evaluate whether changes in the tax system have a positive or negative impact on the B-Index of a country all variables have to be taken into account as a change in tax rates can be overcompensated by simultaneous changes in the incentive regime.

It is also important to keep the methodology of the B-Index and the underlying assumptions in mind when considering the calculated values. E.g. for Canada and Switzerland, sub-national fiscal R&D incentives are disregarded, which tends to result in an overestimate for the respective B-Indices. In turn, where companies are bound by ceilings, B-Indices might be overestimated. In addition, the B-Index only includes input-oriented R&D incentives. Countries that do not offer tax credits, super deductions, accelerated depreciation or reductions of wage withholding taxes might incentivize corporate R&D activity with other measures, like direct grants or output-oriented measures.

All in all, over the years a significant increase in the generosity of input-oriented fiscal R&D incentives can be observed across all cost types. Due to the negative effect of depreciation rules, the values of the B-Indices for buildings and machinery and equipment lie above the values of the B-Indices for labor and other current costs. The majority of countries have an overall B-Index below 1. Within the sample, the development of the B-Indices is subject to sizable variations. This applies to comparisons across time as well as across countries. The B-Indices remain roughly constant over time only for a small fraction of the countries considered, where most of those countries do not offer any input-oriented R&D incentive at all.

4. Quantitative analysis of the effectiveness of fiscal R&D incentives

4.1. Literature review

Input-oriented R&D tax incentives have existed for a long time, therefore numerous empirical studies have been conducted that investigate their effects and effectiveness with regards to the promotion of R&D investment. Among those, a few use the B-Index introduced by Warda (2001) as a main independent variable of interest.

Guellec and de la Potterie (2000) investigate the effect of several measures of government funding, among them the B-Index as a proxy for fiscal incentives. Their study covers 17 countries for the 1983-96 period. They find a significant negative impact of the B-Index on privately funded R&D. The negative impact increases with a one-year time lag. However, the effect gets substantially smaller and insignificant for a time lag of two and more years. They conclude that fiscal incentives have a rather short-term impact.

Falk (2006) studies the factors influencing business-sector R&D intensity in a panel of 21 OECD countries from the time period 1975 to 2002. As dependent variable, he uses five-year averages of the total expenditure on R&D in the business sector as a percentage of GDP, aggregated at country level. The B-Index as a measure for the overall generosity of R&D tax incentives is included as one of the main independent variables of interest. He finds significant negative effects of the B-Index on R&D expenditure in the business sector. This indicates that an increase in the generosity of fiscal R&D incentives (which leads to a decrease in the B-Index) leads to an increase in the amount companies spend on R&D investment, especially in the longer term.

In a study analyzing firm-level data for Spanish companies based on a 2002 survey, Corchuelo and Martínez-Ros (2010) investigate the effectiveness of fiscal R&D incentives in Spain. R&D spending over sales represent the dependent variable, R&D technological effort. The independent variable B-Index approximates the benefits a firm expects from its R&D investment. They show that the fiscal R&D incentives have a positive effect on R&D technological effort, with significant values for large firms.

Ernst and Spengel (2011) conduct a study covering 19 EU-countries plus Norway for the time period of 1998 to 2007 and firm-level data on patent applications. They use the number of patent applications to approximate the firm-specific scale of R&D investment. The yearly B-Indices are calculated for each country as a measure for the tax incentives in the R&D phase. For a binary choice whether to invest in R&D or not, they find a significant negative effect of the B-Index, i.e. a positive effect of fiscal R&D incentives in the investment probability.

Westmore (2013) carries out a macro-economic study that includes 19 OECD countries for the time period of 1983 to 2008. When investigating the relationship between business R&D expenditure (aggregated at country-level) and the B-Index he finds a significant negative effect. The impact is found to be substantially larger in the long run compared to the short run.

In summary, all studies find a significant negative impact of the B-Index on R&D investment. The empirical evidence therefore indicates that input-oriented fiscal R&D incentives increase the amount companies invest in their R&D projects. Output-oriented R&D incentives started to grow in popular-

[37] Please also refer to Table A - 1 and the related notes in the appendix.

ity over the last decade. Given the rather brief period of time IP boxes existed, empirical evidence on their effects is rare. Studies in this field mostly concentrate on the relationship of IP boxes and the number of patent applications as well as the location of patents. Ernst and Spengel (2011) find a negative effect of tax rates on the number of patent applications and suggest that decreasing tax rates will lead to increasing patent applications. Bradley et al. (2015) also find a significant increase in patent applications after the introduction of IP boxes. However, they note that a major part of this development could be tied to the patenting of already existing innovations that had not been patented before (as opposed to new innovations). Evers et al. (2015) find that IP boxes lead to a substantial reduction in effective average tax rates (EATRs) and, depending on the design, reduce the cost of capital of R&D projects. However, they suggest that the incentivisation to increase real R&D investment may be obstructed by tax planning strategies via the movement of mere book profits. Karkinsky and Riedel (2012) suggest that, overall, multinationals tend to locate patents in low-tax countries. This finding is supported by Griffith et al. (2014), who add that the sensitivity to tax policy changes varies depending on the country. To the best of my knowledge, there currently exists no empirical evidence that IP boxes have a significant effect on R&D investment.[38]

4.2. Empirical data and descriptive statistics

As described above, the purpose of this section is to investigate the effect of fiscal R&D incentives on R&D investment. Therefore, R&D expenditure is established as the dependent variable. The data stems from the Research and Development Statistics from the OECD Database. In this dataset, R&D expenditure is aggregated at the country-level and displayed in different segments. For the analysis, business enterprise R&D expenditure (BERD) by industry and by type of cost is used, denoted in 2010 dollars with constant prices and purchasing power parity (PPP)[39]. The total BERD is sub-divided into six industry sectors: firstly agriculture, hunting, forestry and fishing (from here on denoted as agriculture), secondly mining and quarrying (from here on denoted as mining), thirdly manufacturing, fourthly electricity, gas and water supply (from here on denoted as electricity), fifthly construction and lastly services sector.[40] This data is complemented by BERD by industry by main activity, applying the same denotation as the basis data set. Where missing values were added, I checked that the numbers that were available in both data sets for the respective countries matched. The data on BERD by industry is collected for 34 different countries over the period 1991-2014.

[38]See also see De Rassenfosse (2015), p. 15, Alstadsæter et al. (2015), pp. 2-3.

[39]PPPs eliminate the effects of different price levels between countries, see OECD (2007).

[40]The classification of economic activities into industries follows ISIC Rev. 3.1.

The first main variable of interest are input-oriented fiscal R&D incentives, represented by the B-Index. This methodology is also used in other empirical studies to measure input-oriented fiscal R&D incentives, e.g Falk (2006), Corchuelo and Martínez-Ros (2010), Ernst and Spengel (2011), Westmore (2013) and Bösenberg and Egger (2017). The particular values used in the analysis are those calculated based on the methodology presented in the preceding chapters.[41] A decrease in the B-Index represents more generous tax incentives, therefore I expect an increase in R&D investment.

The second main variable of interest are output-oriented fiscal R&D incentives, represented by a dummy variable that takes the value of 1 if an IP box regime exists and the value of 0 otherwise. Table 2 in chapter 3.1 is used as basis for the dummy variable. In line with the existing empirical literature already mentioned in the preceding chapter, I do not expect significant effects of IP boxes on R&D expenditure.

Several country-specific control variables are applied. Firstly, the corporate income tax rates (CIT) control for the location decision of MNEs, as applied by Ernst and Spengel (2011). The CIT stems from the OECD Tax Database, Table II.1. The tax rates used in the analysis are combined corporate income tax rates which include central and regional statutory tax rates. As especially for the period 1991 to 1999 not all tax rates are available, the data is complemented with tax rates provided by the IBFD in its annual European Tax Handbook. As higher tax burdens decrease the capital available for investment, a negative effect on R&D investment is expected.

GDP per capita is used as a control for living standard, following Lederman and Maloney (2003) who found that a higher level of development is associated with more R&D investment. The relevant data is taken from the National Accounts from the OECD database. The GDP per head is denoted in 2010 dollars with constant prices and PPP.[42]

The population controls for country size, as applied by Ernst et al. (2014). The numbers were taken from the estimates of the total population by major area, region and country in the 2015 Revision of World Population Prospects provided by the UN Population Division.[43]

The number of students enrolled in tertiary education divided by population covers effects from human capital, as suggested by Bebczuk (2002). The required data on students is provided by the OECD Education and Skills Database where students enrolled by type of institution are accounted for up to 2012. The data on population stems from the UN, as already explained above. A higher level of human capital is expected to be associated with more R&D investment.

To account for property protection,[44] the property index of the index of economic freedom, provided by the Heritage

[41]Please refer to Table A - 4 in the appendix.

[42]Availableunderhttps://stats.oecd.org/Index.aspx?DataSetCode=GERD_FUNDS.

[43]Availableunderhttps://esa.un.org/unpd/wpp/Download/Standard/Population/.

[44]See e.g. Karkinsky and Riedel (2012) that also use the index of economic freedom as a control variable.

Foundation, is included.[45] The index appoints a score from 0 (private property is outlawed) to 100 (private property is guaranteed and protected)[46] to each country and is available for the years 1995 to 2014 in the sample. As the index varies only marginally, the values appointed in the earliest year available are assumed for the preceding years for the purpose of the analysis. The protection of property rights, which also includes intellectual property, guarantees a company the possibility to exploit the results of its investment. Therefore, a positive effect of property protection on R&D investment is expected.

In addition, year- and country-fixed effects are included.

In Table 4, the variables are summarized. With a sample of 34 countries over a period of 24 years, a maximum of 816 observations can be reached for each variable. The regression is mainly limited by the data for R&D expenditure, with only 576 observations for total R&D expenditure and even less observations if sub-divided into the industries. The values differ considerably across countries and time, especially for the total, manufacturing and services sector. Due to the high numbers a logarithm is applied for purpose of the analysis. The total B-Indices range between 0.936 and 1.179, with the values for the B-Indices for machinery and equipment and buildings being considerably higher than for labor and other current costs. Since the availability of data on CITs limits the number of B-Index that can be calculated, the variables have an equal amount of observations.

4.3. Estimation strategy

To capture the effect fiscal R&D incentives on R&D investments, the ordinary least squares (OLS) method is applied. The estimating equation is given by

$$\begin{aligned} ln(R\&D_total)_{it} =& \beta_1 * B_Index_total_{it} + \beta_2 * IP_Box_{it} \\ &+ \beta_3 * CIT_{it} + \beta_4 * ln(GDPpCap)_{it} \\ &+ \beta_5 * ln(Population)_{it} \\ &+ \beta_6 * StudentsspCap_{it} \\ &+ \beta_7 * PropertyProtection_{it} \\ &+ \alpha_i + \lambda_t + \epsilon_{it} \end{aligned} \tag{13}$$

where subscript i denotes the ith country (i = 1, ..., 34) and subscript t denotes the tth period (t = 1, ..., 24). R&D_total$_{it}$ is the aggregated business sector R&D expenditure in country i in year t. If particular industries are considered, in formula 13 R&D_total$_{it}$ is replaced by R&D_agriculture$_{it}$, R&D_mining$_{it}$, R&D_manufacturing$_{it}$, R&D_electricity$_{it}$, R&D_construction$_{it}$ and R&D_servicesector$_{it}$. B_Index_total$_{it}$ represents the generosity of input-oriented fiscal R&D incentives. If particular expenditure types are considered, B_Index_total$_{it}$ is replaced by B_Index_ME$_{it}$, B_Index_B$_{it}$, B_Index_L$_{it}$ and B_Index_OC$_{it}$. IP_Box$_{it}$ denotes a dummy for the existence or absence of IP box regimes in a given country i and year t. CIT$_{it}$, GDPpCap$_{it}$, Population$_{it}$, StudentspCap$_{it}$ and PropertyProtection$_{it}$ account for the control variables listed in Table 4. The terms α_i and λ_t are country- and time-fixed effects respectively. ϵ_{it} denotes white noise.

4.4. Results

4.4.1. Baseline results

Table 5 presents the main regression results by industry sector. For each sector, the regression is run three times: In the first and second column, the total B-index and the IP box dummy are regressed separately, each time only with country- and year-fixed effects. In the third column, both main independent variable of interest are regressed, this time with the full set of control variables.

Consistent with past studies, the results suggest a negative effect of the B-Index on R&D investment. The effects are significant at the 5%-level for total BERD and in the services sector and at the 10%-level in the manufacturing sector. In the other four sectors the relationship is insignificant. This indicates that sectors matter with regards to the effects of input-oriented fiscal R&D incentives. Similarly, Castellacci and Lie (2015) find in their meta-study that, compared to other sectors, R&D investment in the services sector increases at a significantly higher rate in response to the introduction of tax credits. They argue that companies in the services sector have in general a lower R&D intensity, thus it is easier for them to increase their R&D investment compared to companies that already maintain a high R&D expenditure level.

Quantitatively, the β_1 of -0.87 in case of total R&D expenditure indicates that a reduction in the B-Index by 0.10 (i.e. a 1 dollar investment in R&D has to earn 10 cent lower pre-tax income to reach the break-even point) increases total BERD by 8.7%. On the industry level, the effects have similar magnitudes with an expected increase in industry-specific BERD of 8.8% and 7.9% in the manufacturing and the services sector, respectively. In comparison, Guellec and de la Potterie (2000) and Falk (2006) find substantially lower short-run elasticities of -0.16 and -0.22, respectively. Both use older time periods (1983-1996 and 1975-2002, respectively) and fewer countries (17 and 21, respectively). Therefore, the difference could be attributed to the more recent and extended sample. The insignificant effects for IP boxes are in line with the expectations. It suggests that the introduction of IP box regimes indeed has no influence on the level of business R&D expenditure in a country. Alstadsæter et al. (2015) list several possible reasons. For one, the award of successfully patented innovations discriminates commercially less exploitable but socially potentially more advantageous research. In addition, patent box regimes do not link the tax savings to R&D investment.[47]

[45] Available under http://www.heritage.org/index/explore?view=by-region-country-year. This index was used to account for property protection as the more widely used Ginarte-Park index of patent rights is only available up to 2005, see Park (2008).

[46] See Heritage Foundation (2017).

[47] See Alstadsæter et al. (2015), p. 3.

Table 4: Descriptive statistics; Notes: "log" indicates that the variable is put in natural logarithm in the regression.

Variable	Obs	Mean	Std. Dev.	Min	Max	Scale
R&D Exp (in 2010 dollars, constant prices and PPPs)						
- Total	567	18,290.350	44,222.330	17.726	296,465.700	log
- Agriculture	391	49.104	74.518	0.003	418.099	log
- Mining	373	140.238	371.693	0.013	3,005.693	log
- Manufacturing	506	15,030.340	34,253.330	11.617	208,018.900	log
- Electricity	414	134.320	200.827	0.031	1,025.707	log
- Construction	403	181.569	372.681	0.034	1,888.687	log
- Services	497	4,148.760	12,941.800	3.244	95,258.890	log
Variable	Obs	Mean	Std. Dev.	Min	Max	Scale
B-Index						
- Total	785	0.936	0.126	0.473	1.179	
- ME	785	1.011	0.143	0.437	1.267	
- B	785	1.243	0.186	0.714	1.827	
- L	785	0.912	0.138	0.335	1.199	
- OC	785	0.921	0.133	0.429	1.199	
IP box (Dummy Variable)	816	0.098	0.298	0.000	1.000	
CIT (0 - 1 scale)	785	0.310	0.081	0.125	0.582	
GDP per capita (in 2010 dollars, constant prices and PPPs)	805	31,718.690	13,637.680	1,601.623	90,628.360	log
Population (in thousands)	816	70,300.000	218,000.000	257.387	1,370,000.000	log
Students in tert. education per capita	648	0.238	0.038	0.001	0.349	
Property Protection Index (0 - 100 scale)	816	77.249	16.519	20.000	95.000	

There is mixed evidence on the relationship between the R&D expenditure and the CIT of a country. In the manufacturing sector, the results suggest a positive effect, while in the electricity sector a strong negative impact, which was originally expected, is found. Nevertheless, both effects are only significant at the 10%-level. For the log GDP per capita and the number of students in tertiary education per capita, significant positive effects are only found in the manufacturing sector. The direction of the effect is consistent with the expectations in both cases. However, the results in the other sectors show mixed algebraic signs for the two variables. The log population is significantly positively related to BERD as well for the total across sectors as for three out of the six sectors. In case of the total R&D expenditure the results is even significant on a 1%-level. As for the property protection index, the results show a rather small significant positive relationship on a 10%-level in the agriculture sector, the effect is insignificant and also small in all other sectors.

In every sector, the adjusted R-squared shows that the estimation improves when the control variables are added. In the specification with the total business-financed R&D investment as well as BERD in the manufacturing and the services sector, the values lie between 56% and 75%. However, in the other four of the industries (agriculture, mining, electricity, construction), the adjusted R-squared is low in comparison, amounting to values between 6% and 17% with controls added. This seems to indicate that in the four industries mentioned other influences exist that have not been included in the analysis. Significant effects of fiscal R&D incentives are only observed in the two sectors where the explained variance is comparably high. It might be possible that, by controlling for the missing influence factors in the four sectors mentioned above, significant results can be obtained in more sectors. Determining those control variables remains a question for future research.

Overall, the results suggest that input-oriented fiscal R&D incentives have a significant negative impact on R&D investment. The magnitude of those effects seems to depend on the respective industries. I did not find significant effects with regards to output-oriented fiscal R&D incentives, i.e. IP boxes.

4.4.2. Extended analysis

To consider the case that companies only react over time to newly introduced R&D incentives, I repeated the regression with a lagged BERD. The repetitions were conducted with a lag of one, two and five years (Table 6).

First, the magnitude and significance of the effects decreased with time. In case of the 1-year-lag, the significantly negative effect for BERD in total and in the services sector decreases, the significantly negative effect in the manufacturing sector vanishes. The results for total BERD contrast with Guellec and de la Potterie (2000), where the negative effect nearly doubles with a one-year-lag compared to the specification with no lag; both times having a significance level of

Table 5: Regression results by industry sector; Notes: *, **, and *** indicate significance at the 10, 5 and 1% level.

		Total			Agriculture			Mining			Manufacturing			Electricity			Construction			Services	
	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls
B-Index Total	-0.59		-0.87**	-0.98		-0.67	0.35		0.46	-0.70		-0.88*	0.01		-0.18	-0.07		0.29	-1.07**		-0.79**
IP box		-0.17	-0.10		0.14	0.10		-0.14	-0.04		-0.10	-0.12		-0.16	0.07		0.07	0.00		0.25	0.24
CIT			0.63			1.69			3.66			1.07*			-4.15*			3.94			-0.85
log GDP per capita			0.50			-1.03			-2.74			1.01***			0.64			-1.00			-0.08
log Population			2.87***			3.97			10.25**			2.07*			5.81**			6.99			0.91
Students in tert. education per capita			1.52			2.44			1.70			2.95**			1.52			-3.29			-0.63
Property Protection Index			0.00			0.02*			-0.01			-0.01			0.02			0.03			0.00
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	550	567	488	389	391	345	371	373	330	499	506	444	412	414	381	399	403	362	492	497	437
Adjusted R^2	0.59	0.56	0.72	0.03	0.03	0.06	0.03	0.03	0.13	0.45	0.42	0.56	0.03	0.03	0.10	0.08	0.07	0.17	0.69	0.65	0.75

Table 6: Regression results for total B-Index by industry sector (lagged BERD); Notes: *, **, and *** indicate significance at the 10, 5 and 1% level.

Industry Sector	Controls	no lag	1 year lag	2 year lag	5 year lag
Total		-0.59	-0.46	-0.38	-0.46
	x	-0.87**	-0.78*	-0.69	-0.41
Agrar		-0.98	-1.17	-1.48	-0.64
	x	-0.67	-0.75	-1.15	-0.81
Mining		0.35	-0.12	-0.56	-2.13*
	x	0.46	0.24	-0.12	-1.24
Manufacturing		-0.70	-0.54	-0.48	-0.70
	x	-0.88*	-0.77	-0.68	-0.76
Electricity		0.01	-0.65	-0.80	-1.31*
	x	-0.18	-0.89	-0.73	-1.19*
Construction		-0.07	-0.61	-0.80	-1.57
	x	0.29	-0.48	-0.32	-1.25
Services		-1.07**	-0.89*	-0.71	-0.28
	x	-0.79**	-0.79**	-0.61	-0.01

1%. In their study they do not differentiate between industry sectors. In case of the two-year-lag, the results did not show any significant relationship, which now is in line with the findings of Guellec and de la Potterie (2000).

Guellec and de la Potterie (2000) do not find any significant effect of the B-Index on total private R&D expenditure with a four-year-lag. Again, this matches my results for total BERD in the regression with a lag of five years. In contrast, the results indicate negative effects in the mining and electricity sector, al-though only significant at a 10%-level. Interestingly, in those two sectors no significant impact was found in the original setting. With a β_1 of -2.13 (without controls) and -1.19, respectively, the effects are larger compared to the values found for the specification without a lagged variable. This is in line with Bloom et al. (2002), Falk (2006) and Westmore (2013) which all find larger long-run elasticities compared to the short-run elasticities. However, they only consider total BERD and do not differentiate between industry sectors.

All in all, the time horizon considered seems to be an important variable, too. Companies in the manufacturing and the services sector seem to react quickly to new incentives, while companies in the mining and the electricity sector need some time to adjust. However, especially when interpreting the results under consideration of a longer period in time it has to be kept in mind that fiscal R&D incentives are subject to change. Only some countries like Canada or the USA applied their incentive scheme constantly over more than ten years while for example Spain changed its system every few years.

In a third part of the analysis, I regressed the B-Indices that were calculated for the different cost types on total BERD (Table 7). In addition, the relationship of the B-Indices is investigated with respect to the R&D expenditure in the industry sectors that showed significant effects in the first part of the analysis, the manufacturing sector (Table 8) and the services sector (Table 9).

The results indicate that the generosity of R&D incentives targeted at other current costs has a significant positive effect in all three cases considered, with a magnitude between -0.86 and -1.26 depending on the specification of the regression. In case of the total BERD displayed in Table 7, the B-Indices for the other three cost types show no significant effects. Overall, the tax incentives targeted at other current costs like energy or administration costs seem to have the most impact.

This appears to be reasonable, as they account for around 30% of a company's total expenditure. Since the B-Indices are regressed on total BERD, changes in the tax system that affect other current costs will have a larger effect on the total investment than changes that affect expenditure on machinery and equipment or buildings. Therefore, it might be interesting to repeat the analysis with data on R&D expenditure differentiated by expenditure type. However, considering this explanation it is noticeable that tax incentives targeting labor expenditure, which accounts for around 60%, yield insignificant results. Another possible reason could be that, in the short run, it might be easier to increase other current costs compared to capital expenditure and employment.

Comparing the R&D expenditure in the manufacturing (Table 8) and the services sector (Table 9) yields mentionable results: In the manufacturing sector the B-Index for machinery and equipment has, in addition to the B-Index for other current costs, a significant negative effect on a 5%-level. On the other hand, in the services sector the B-Index for labor has a significant negative effect on a 10%-level. The B-Index for other current costs shows significant negative effects at a 1%-level when the control variables are omitted and at a 5%-level when the control variables are included.

Table 7: Regression results by type of cost, total BERD; Notes: *, **, and *** indicate significance at the 10, 5 and 1% level.

		B-Index Total			B-Index ME			B-Index B			B-Index L			B-Index OC	
	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls
B-Index															
- Total	-0.59		-0.87**												
- ME				-0.44		-0.68									
- B							0.21		0.04						
- L										-0.40		-0.64			
- OC													-0.86*		-1.03***
IP box		-0.17	-0.10		-0.17	-0.01		-0.17	-0.06		-0.17	-0.12		-0.17	-0.04
CIT			0.63			0.99*			0.49			0.54			0.49
log GDP per capita			0.50			0.54			0.34			0.45			0.50
log Population			2.87***			2.86***			2.67**			2.85***			2.86***
Students in tert. education per capita			1.52			1.09			1.52			1.43			2.04
Property Protection Index			0.00			0.00			-0.01*			0.00			-0.01
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	550	567	488	550	567	488	550	567	488	550	567	488	550	567	488
Adjusted R^2	0.59	0.56	0.72	0.59	0.56	0.72	0.58	0.56	0.70	0.58	0.56	0.71	0.60	0.56	0.73

Table 8: Regression results by type of cost, BERD manufacturing sector; Notes: *, **, and *** indicate significance at the 10, 5 and 1% level

		B-Index Total			B-Index ME			B-Index B			B-Index L			B-Index OC	
	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls
B-Index															
- Total	-0.70		-0.88*												
- ME				-0.68		-0.94**									
- B							-0.01		-0.43						
- L										-0.46		-0.60			
- OC													-0.89		-1.02**
IP box		-0.10	-0.12		-0.10	0.01		-0.10	-0.05		-0.10	-0.14		-0.10	-0.05
CIT			1.07*			1.67**			1.71			0.99			0.90
log GDP per capita			1.01***			1.15***			1.05**			0.96**			0.98**
log Population			2.07*			2.15*			1.83			2.04			2.10*
Students in tert. education per capita			2.95**			2.42**			2.64**			2.88**			3.47**
Property Protection Index			-0.01			-0.01			-0.01			-0.01			-0.01
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	499	506	444	499	506	444	499	506	444	499	506	444	499	506	444
Adjusted R^2	0.45	0.42	0.56	0.45	0.42	0.58	0.43	0.42	0.53	0.44	0.42	0.54	0.46	0.42	0.57

Table 9: Regression results by type of cost, BERD services sector; Notes: *, **, and *** indicate significance at the 10, 5 and 1% level.

		B-Index Total			B-Index ME			B-Index B			B-Index L			B-Index OC	
	no controls		controls	no controls		controls	no controls		controls	no controls		controls	no controls		controls
B-Index															
- Total	-1.07**		-0.79**												
- ME				-0.33		-0.19									
- B							0.05		0.14						
- L										-0.81*		-0.56			
- OC													-1.26***		-1.09**
IP box		0.25	0.24		0.25	0.31		0.25	0.29		0.25	0.22		0.25	0.31
CIT			-0.85			-0.74			-1.09			-0.91			-1.03
log GDP per capita			-0.08			-0.15			-0.27			-0.12			-0.08
log Population			0.91			0.79			0.77			0.88			0.99
Students in tert. education per capita			-0.63			-0.68			-0.45			-0.70			-0.10
Property Protection Index			0.00			0.00			0.00			0.00			0.00
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	492	497	437	492	497	437	492	497	437	492	497	437	492	497	437
Adjusted R^2	0.69	0.65	0.75	0.68	0.65	0.74	0.68	0.65	0.74	0.69	0.65	0.74	0.69	0.65	0.75

Following the preceding argumentation, this occurrence could be based on the composition of the total BERD in the respective sectors. While the distribution of expenditure for machinery and equipment and buildings (5%, respectively), labor expenditure (60%) and other current costs (30%) is representative on an overall basis, there might be differences in-between sectors. For example, in the manufacturing sector expenditure on machinery and equipment could make up a larger proportion, whereas in the services sector salaries and wages could account for a greater share. As a result, the importance of R&D incentives targeted at the respective expenditure types would differ depending on the industry sector.

To summarize, the effect of output-oriented fiscal R&D incentives seems to depend on the type of cost the incentive applies to. The B-Index for other current costs is significant in the case of total BERD as well as R&D investment in the manufacturing and the services sector. The B-Indices for machinery and equipment and labor show a significant effect only for the manufacturing and the services sector, respectively.

The regressions in part one to three were also conducted with openness as an additional control variable. It is calculated as the sum of imports and exports in goods divided by GDP. The variable was dropped since it did not yield any significant impact in the regression. In the empirical literature, the importance and sign of openness is ambiguous. Bebczuk (2002) suggests a negative influence. On the other hand Falk (2006) finds positive but statistically insignificant effects while a study conducted by Ernst and Spengel (2011) results in significant positive effects for part of the specifications.

5. Conclusion

This thesis investigates the effect fiscal R&D incentives have on R&D investment. Input-oriented incentives have a long history and are widely spread. Output-oriented incentives are not as common but grew in popularity over the last decade. Both types of R&D incentives are characterized by a wide variety of possible designs. To compare the generosity of input-oriented fiscal R&D incentives, the B-Index methodology was introduced. Like the underlying incentives, the B-Indices vary greatly across countries and over time.

In the empirical analysis, the effects the B-Index and IP boxes have on R&D expenditure, differentiated by industries, are investigated for a sample of 34 countries from 1991 to 2014. Other factors included are living standard, market size, human capital and property protection.

The main results can be summarized as follows. While there are no indications that output-oriented fiscal R&D incentives influence R&D investment in a country, significant positive effects are found for the input-oriented fiscal R&D incentives. The magnitude of the influence seems to depend on the industry observed as well as the time horizon considered. A reduction in the B-Index by 0.10 increases total BERD by 8.7%, BERD in the manufacturing sector by 8.8% and BERD in the services sector by 7.9%. When introducing lagged BERD as the dependent variable, the results suggest that companies in the manufacturing and services sector react within one or two years to changes in the B-Index. Companies in the mining and the electricity sector seem to take a longer period of time to adjust their R&D investment. Another relevant factor is the type of cost the incentives apply to. While the B-Index for other current costs is significant in all specifications, the B-Indices for machinery and equipment and labor are only significant in the manufacturing and the services sector, respectively.

As this study is conducted on an aggregated county level, the estimated effects presented are averages. The effect of fiscal R&D incentives seems to differ depending on the industry. Future research using firm level data could further investigate this relationship with respect to firm size and other specifications. In this setting, it might also yield interesting results to introduce lagged variables or to differentiate between types of costs.

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