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R&D TAX INCENTIVE POLICY FOR PROMOTING R&D AND INNOVATION IN EUROPEAN COUNTRIES: CROSS-COUNTRY STUDY

Theses of PhD Dissertation

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Miskolc, 2023

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Introduction

Due to the contribution that research and development (R&D) makes to productivity and long-term economic growth (Romer, 1990; Aghion and Howitt, 1992) and its high social returns (Hall, Mairesse, and Mohnen, 2010; Bloom, Schankerman, and Van Reenen, 2013) governments are motivated to find appropriate ways to encourage R&D expenditure. R&D tax incentives as a market-based instrument to support business R&D have grown increasingly popular over the last two decades, and as of today are in place in the majority of European countries. Since R&D capital is internationally mobile the development of competitive and attractive tax incentive policy is high on governments' agendas. On the other hand, tax incentives as government expenditures should be justified and consistently evaluated to conclude whether the intended policy outcome has been achieved.

There is a large body of studies aimed at evaluating the effectiveness of R&D tax incentives; however, often they apply different methodological approaches, which make the results less comparable. While most studies evaluate the effect of tax incentives on a country level, there are only a few studies (for example, OECD, 2020b; Thomson, 2017) that assess the overall effect of tax incentives in a cross-country setting. Moreover, there is a lack of such analysis conducted for only European countries.

While empirical research on the effectiveness of R&D tax incentives is a topic often paid attention to in the literature, the development of the theoretical framework of tax incentive policies and methodological approaches to analyse its relative attractiveness lags behind. The B-index model developed by Warda (1997) to assess the relative generosity of the tax systems in stimulating business R&D is widely used today for the analysis of policy attractiveness; however, it describes only potential tax support that may be provided by the tax system and does not reflect perceived attractiveness of tax incentives by firms which may affect tax incentive take-ups. Therefore, it cannot be a complete measure of the attractiveness of tax incentives. Successful implementation of R&D tax incentive policy may play a crucial role in the policy effectiveness; however, there are no studies found which would define and evaluate the relative efficacy of policy implementation, as well as the main drivers of its heterogeneity among countries. Moreover, there is a need to conduct additional research on the desired characteristics of R&D tax incentive schemes, since the main efforts in this direction were made by the European Commission and took place in 2014. While policymakers introduce tax incentives based on their own expertise, there is a need to establish a conceptual framework on how decisions on the introduction and selection of the generosity of new R&D incentives should be made.

Addressing the existing gaps in the literature, the *aim of this research* is to develop theoretical and methodological aspects of R&D tax incentive policy as well as to provide empirical evidence on its effectiveness in a cross-country setting.

The research is intended to answer the following *research questions*:

1. What is the role of R&D tax incentives in the policy mix to promote R&D and innovation?

2. What are the main practices of R&D tax incentive policy utilised in European countries?

3. How can the decision-making process involved in the introduction and selection of the generosity of tax incentives be structured?

4. What could be a measure of efficient implementation of R&D tax incentives applicable for cross-country comparisons?

5. Are R&D tax incentives effective in incentivising additional R&D and innovation in European countries from a cross-country perspective?

6. Is there a positive association between business R&D expenditure and productivity in European countries from a cross-country cross-industry perspective?

7. What factors play a role in successful implementation of R&D tax incentive policy?

8. How can the effect of more efficient implementation of R&D tax incentives on private R&D investment be evaluated in a cross-country setting?

9. What are the best practices of R&D tax incentive schemes?

10. What are the methodological aspects of enhancing comparability of R&D tax incentive evaluations?

The *objectives* of the study are:

1. investigating the role and the main practices of R&D tax incentive policy utilised in European countries;

2. developing a decision-making model on the introduction of R&D tax incentive schemes and their generosity;

3. analysing the methodological framework underlying the assessment of tax incentives attractiveness and effectiveness;

4. developing a methodology for assessment of the efficient implementation of R&D tax incentive policy;

5. evaluating the first- and second-order effects of R&D tax incentives in terms of additional R&D investment and patent applications in a cross-country setting;

6. assessing the strength of association between business R&D expenditure and productivity in a cross-country cross-industry setting;

7. investigating the reasons behind heterogeneous efficiency of R&D tax policy implementation in European countries;

8. modelling the effects of changes in the efficiency of tax incentive policy implementation on business R&D investment;

9. identifying best practices and desired features of tax incentive schemes;

10. developing a methodological framework enhancing the cross-country comparability of R&D tax incentive evaluations.

Data sources. The OECD and Eurostat databases were extensively used in the research. Specifically, "Science, Technology and Patents" by the OECD provided data on R&D tax incentive indicators (i.e. the amount of tax support of R&D and tax subsidy rates on R&D expenditure) and research and development statistics, complemented by more detailed statistics of Eurostat on gross domestic expenditure on R&D by sectors of performers and source of funds and statistics on business enterprise R&D expenditure by NACE Rev. 2 activity and source of funds, and by size class and source of funds derived from "Science and Technology" database. Supplemented by other OECD and Eurostat datasets (such as "Industry and Services", "National Accounts", "Globalisation", "Industry, Trade and Services structural business statistics"), these data were the core of the investigation. Additionally, the database of the World Intellectual Property Organization (WIPO) served as a source of data on the number of resident patent applications by country, and the Global Competitiveness Report published by the World Economic Forum informing about countries' institutional scores served as a basis for the cluster analysis.

Structure of the dissertation. The study consists of three chapters. The first chapter describes the role of tax incentives in promoting business R&D and main practices used in shaping R&D tax incentive policy in European countries. The main choices in the policy design are investigated and a decision-making model on implementation and generosity of R&D tax incentives is introduced. The methodological approaches to R&D tax incentive evaluations and the evidence on the policy effectiveness are described.

The second chapter describes the drawbacks of the B-index model as a sole indicator of the attractiveness of the R&D tax incentive system, and suggests a novel complementary approach to analysing the attractiveness of tax incentives considering efficacy of their implementation, namely the tax incentive implementation (utilisation) rate. It further develops and evaluates a structural model of first- and second-order effects of R&D tax incentives in

European countries. The strength of association between productivity and business R&D expenditure is assessed at a cross-country cross-industry level as a potential source of positive third-order effects of tax incentives.

The third chapter investigates the heterogeneity in the efficiency of implementation of R&D tax incentives in European countries and the potential factors which may cause such differences. The strength of association between tax incentive implementation rate and strength of institutions in European countries is assessed. Cluster analysis is conducted to group countries based on similarities in their institutional framework and efficacy of policy implementation. Furthermore, the application of tax incentive implementation rate (TIIR) in policy analysis is demonstrated; the relevant TIIRs are calculated and analysed for 20 European countries (including Turkey) from 2001 to 2019; in addition, modelling of tax support and additional business R&D investment is performed based on the benchmark countries' TIIRs. The chapter further describes the benchmarking of European R&D tax schemes and proposes additional criteria to identify best practices. The necessity of improving the cross-study comparability of existing methods of estimating the tax price of R&D is pointed out, and new approaches for its computation are introduced. The directions of improving the comparability of the introduced measure of TIIR are described.

Contribution of the research. The research *contributes to the existing literature* on the methodological aspects of the B-index framework (Warda, 2001, 2005), which is widely used in the recent studies assessing the effectiveness of R&D tax incentives (Agrawal, Rosell, and Simcoe, 2020; Dechezlepretre et al., 2020; Guceri and Liu, 2019; Rao, 2016; Holt, Skali, and Thomson, 2021) and official countries' evaluations of R&D tax incentive policy (Scott and Glinert, 2020; Fowkes, Sousa, and Duncan, 2015). Moreover, it supplements the existing literature presenting the evidence of additionality of R&D tax incentives in a cross-country setting (OECD, 2020b; Thomson, 2017). It further contributes to the studies on the desired characteristics of R&D tax incentive schemes (European Commission, 2014a). The research identifies *a novel method* for assessing the effectiveness of implementation of R&D tax incentives through TIIR (TIUR) and demonstrates its applicability in policy analysis. Furthermore, summarising the historical experience on the introduction of R&D tax incentives schemes and current trends in R&D policy applications, *a new decision-making model* on the introduction and selection of the generosity of R&D tax incentives is developed that can support policymakers.

2 Thesis statements and research results

***Thesis statement 1*. R&D tax incentives play an increasingly important role in the policy mix to promote private R&D investment and dominate over direct funding of R&D in most European countries.**

The changes in the structure of government support of business R&D were analysed for a set of European countries from 2001 to 2017. In Figure 1 it is shown that in the early 2000s direct financing of R&D was the main measure of government support of business R&D, while indirect government support through tax incentives was provided in only nine European countries.

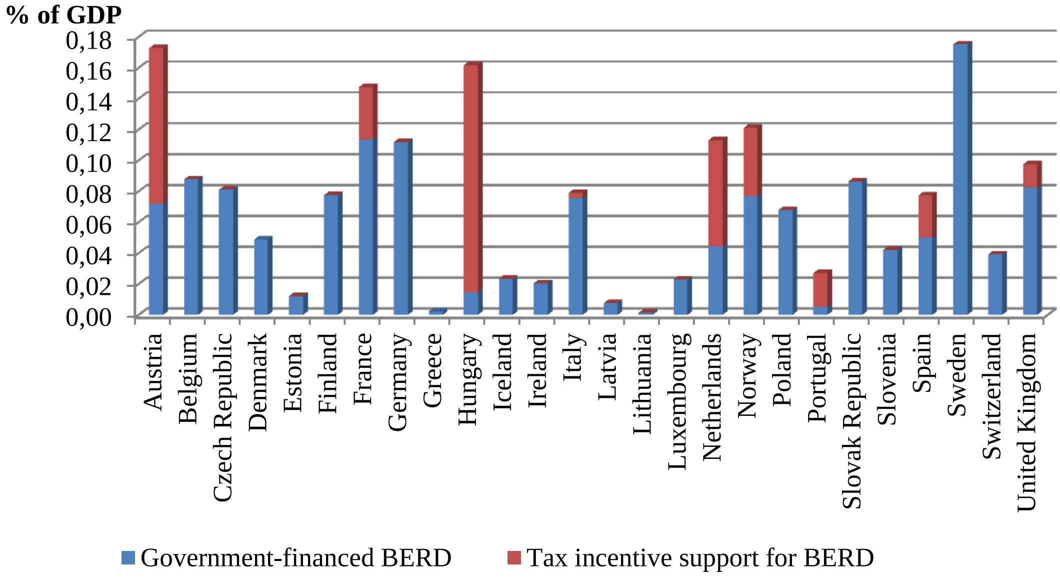

***Figure 1* – Direct government funding and tax support for business R&D in European countries, 2001**

Note: figures for Austria are for 2002, for Hungary 2004, for tax incentive support in Norway 2002, for Luxembourg and Switzerland 2000, for Spain 2002.

Source: own construction based on the OECD Science, Technology and Patents Database – R&D Tax Incentive Indicators, July 2021 (OECD, 2021a.).

In the following years, the internationalisation of the markets and the strategic focus of many OECD countries on R&D as a key factor of competitiveness and economic growth brought new attitudes towards R&D tax incentive policies. While direct financing could be applied to a limited number of applicants (OMC Crest Working Group, 2006), tax incentives were more suited in principle to encourage R&D activities oriented towards the development of applications that had the potential to be brought to the market within a reasonable timeframe (DSTI/IND/STP, 2016). Therefore, R&D tax incentives became the means of attracting the R&D activities of multinational corporations, which typically accounted for a substantial share of business R&D expenditure. Besides, compared with direct subsidies, tax incentives tended to be more compliant with international trade and competition rules (OECD, 2014). Exemptions from international agreements made tax support for R&D one of the few ways that governments could help domestic firms improve competitiveness without direct state aid.

Therefore, during the next decade the distribution of direct and indirect (tax incentive) support changed among European countries (Figure 2).

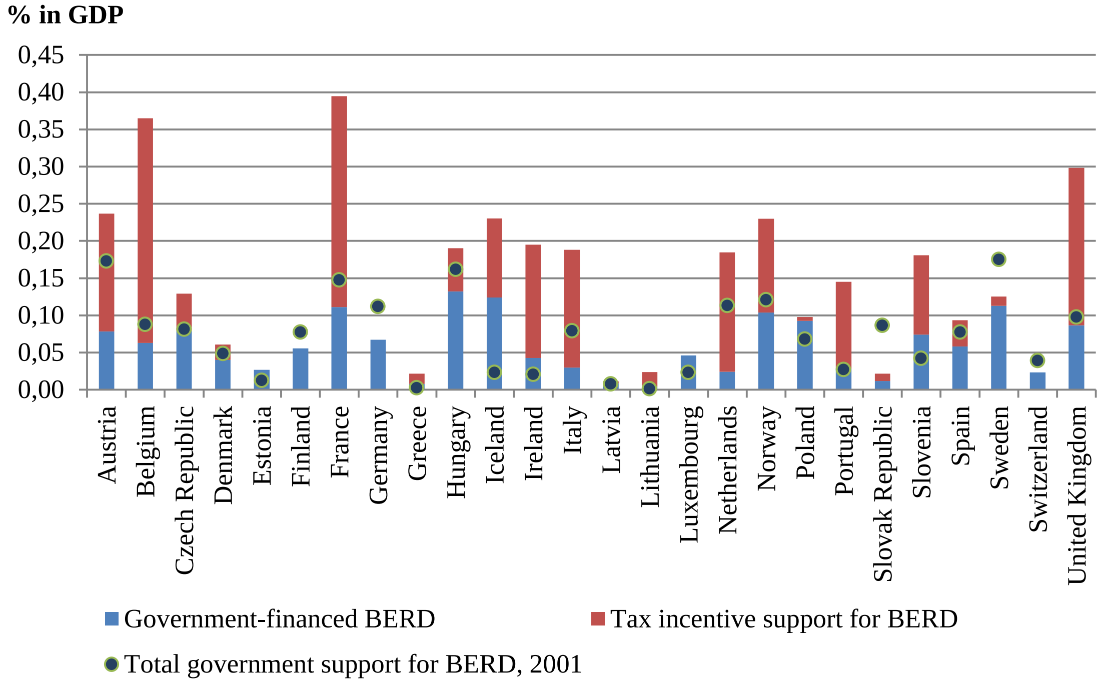

***Figure 2* – Direct government funding and tax support for business R&D in European countries, 2017**

Note: figures for Greece are for 2016.

Source: own construction based on the OECD Database – R&D Tax Incentive Indicators, July 2021 (OECD, 2021a).

As seen in Figure 2, while many countries continued supporting business R&D by direct measures, tax incentives were adopted in the majority of European countries and became a prevailing measure of government support.

***Thesis statement 2*. The policy decisions on implementation and generosity of R&D tax incentives should be consistent and take into account the state of the government**

budget, the given country's involvement in the international tax competition for foreign R&D capital, and the elasticity of foreign and domestic business R&D investment to the size of tax stimuli.

The historical experience of the introduction of R&D tax incentives and changes in the generosity of R&D tax incentive schemes have been investigated. Logical methods such as comparison and induction were used to build a theoretical decision-making model on implementing and selecting the generosity of R&D tax incentives (Figure 3).

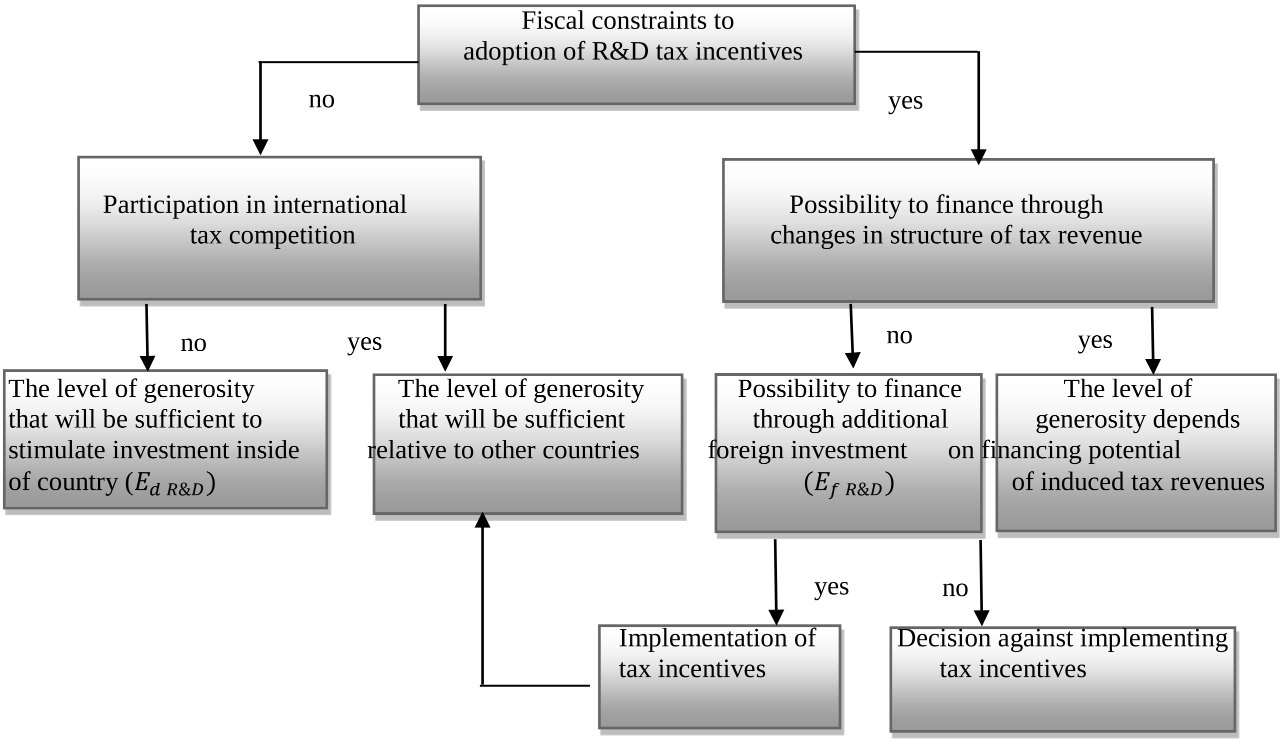

Figure 3 **– Decision making model on implementation and generosity of R&D tax incentives**

Note: $E_{d\ R\&D}$ and $E_{f\ R\&D}$ indicate elasticities of domestic and foreign business investment, respectively, to R&D tax incentives.

Source: own construction.

According to the developed model, the key points in the decision-making process are the existence of fiscal constraints to the adoption of R&D tax incentives and the country's openness to international investment. A country which has disciplined public finances has more flexibility when designing tax incentive schemes. However, in the presence of fiscal constraints, a government should consider possibilities to finance future tax relief. It may decide to increase tax revenues through changes in its structure (for example, by increasing tax rates, broadening the tax base or removing unjustified tax expenditures), or it may introduce R&D tax incentives, expecting that they will attract additional investment primarily from the foreign business sector that will contribute to tax revenues of the domestic economy. In this case, the elasticity of foreign R&D investment to tax parameters is important. It was pointed out that even generous tax incentives may not always lead to additional R&D investment if the elasticity of foreign R&D is low due to the prevalence of low and medium-low technological industries in the economy.

The model can be applied by countries which prioritise innovation development of the economy and recognise the importance of tax assistance in achieving R&D state targets.

Thesis statement 3. **The novel indicator of the tax incentive implementation (utilisation) rate can be used as an additional measure of relative attractiveness of R&D tax incentive schemes and as a methodological tool for an assessment of the efficient implementation of R&D tax incentives.**

It was demonstrated that the current methodological framework – the B-index – acts as a notional measure of tax support that potentially can be provided and does not reflect other aspects of tax incentive schemes which may affect tax incentive take-ups (for example, such as attractiveness of tax incentives in terms of their availability, simplicity, and ease of use). The developed indicator of tax incentive implementation (utilisation) rate allows the generosity of tax incentives to be linked with practical implementation of tax incentive policy while taking into account the actual amount of tax support received by firms.

The tax incentive implementation (utilisation) rate was defined with the following formula:

$$R\&D\ tax\ incentive\ implementation\ rate = \frac{\frac{Tax\ support, as\ a\ \%\ of GDP}{Business - financed\ R\&D, as\ a\ \%\ of GDP}}{1 - B - index}. \qquad (1)$$

In Formula 1, the business-financed GERD (or BERD) by domestic and foreign business-enterprise sectors (where applicable) should be considered depending on the eligibility of certain R&D expenditures. The proposed indicator may be named as the tax incentive implementation rate (TIIR) to emphasise how government succeeds in implementation of R&D tax incentive policy (such as creating a clear mechanism for the usage of tax incentives, transparent application procedure, delivering information about new tax incentives to taxpayers, etc.), or the tax incentive utilisation rate (TIUR), indicating whether business finds it reasonable to claim and use tax incentives for R&D. The formula of TIIR (TIUR) is general and should be adapted to each country’s specific circumstances.

The following features of national R&D tax incentive systems and the reporting on R&D tax expenditures have been considered:

1. differentiation of tax support based on the firms' size;
2. existence of refundable and carry-over provisions, and their modelling in the B-index;
3. the method of measurement of government tax relief for R&D;
4. tax treatment of subcontracting costs;
5. existence of limitations in R&D tax relief.

The specific tax incentive implementation rates have been modelled for 18 European countries for the period from 2001 to 2019 based on the features of national R&D tax incentive systems and the reporting practices on R&D tax expenditures to demonstrate the practical appropriability of the developed indicator. Conclusions about the changes in the efficiency of implementation of tax incentives were drawn for each country. Relative attractiveness of R&D tax incentives was additionally assessed by cross-country comparisons of TIIRs.

Thesis statement 4. **R&D tax incentives lead to positive first- and second-order effects in terms of additional R&D business investment and the number of patent applications.**

A structural equation model was estimated for 18 European countries[1] for 2015 and 2017, years for which the most comprehensive and reliable data were available, in the two following forms:

a) SEM_1:

$$\begin{cases} BFRD_i = \beta_1 + \beta_2 ETT_i + \beta_3 DF_{R\&Di} + \varepsilon_i \\ Patents_i = \gamma_1 + \gamma_2 BFRD_i + \upsilon_i \end{cases}, \quad (2)$$

b) SEM_2:

$$\begin{cases} BFRD_i = \beta_1 + \beta_2 ETT_i + \beta_3 DF_{R\&D(excep\_of\_business)i} + \varepsilon_i \\ Patents_i = \gamma_1 + \gamma_2 BFRD_i + \upsilon_i \end{cases}. \quad (3)$$

Since the structure of direct government support varies among countries and may have heterogenous effect on business-financed R&D, the two models (SEM_1) and (SEM_2) were constructed to separate the effects of direct support to all sectors (gross expenditure on R&D – GERD) and direct support of R&D expenditure, except those attributed to the business enterprise sector. Such effects have not been studied previously, since only government

[1] Including Turkey.

support of business enterprise R&D was commonly used as one of the regressors (for example, in the OECD microBeRD project (OECD, 2020b); by Westmore (2013) and Knoll et al. (2021) as a control variable). Introduction of these variables into the equation is expected to capture some uncontrolled heterogeneity among countries while reflecting other countries' specific characteristics (such as the development of R&D infrastructure, quality and quantity of R&D personnel, and the overall level of R&D expertise).

According to preferred models, the additional business investment in R&D due to tax incentives was estimated at 1.63 in 2017 and 1.08 in 2015. The figures are in line with the recent OECD microBeRD project (OECD, 2020b) which reports the additionality ratio of 1.409 based on the sample of ten OECD countries (nine European countries and Australia) for the period 2016–2019. The number of additional patent applications by countries' residents is estimated at an average of 59 per 0.10 per cent of tax support in GDP, suggesting that 32.3 per cent of total patent applications in 2017 were due to R&D tax incentives. For the year 2015, on average 37 additional patent applications were induced by 0.10 per cent of tax support in GDP, i.e. 20.5 per cent of total patent applications by countries' residents were due to R&D tax incentives. The model also assessed the additionality in business investment in R&D induced by the direct support of gross expenditure on R&D (GERD). The estimated coefficients are 1.429 for 2017 and 1.671 for 2015, which are in line with the OECD microBeRD project estimates for direct support of business R&D being at 1.373 (the OECD analysis covered twelve European countries and five OECD non-European countries for the period from 2016 to 2019). The higher additionality of direct funding over R&D tax incentives in 2015 could be explained by it being a post-crisis period when many businesses facing difficulties in financing their R&D activities more often used tax incentives as substitutes for their own R&D expenditure, while government funding had a more restrictive nature and often had to be complemented by partial financing of R&D projects through the firm's own funds. The alternative models specified for 2017 and 2015 years have demonstrated that direct government support of R&D outside the business sector brings higher additionality than government support of GERD in terms of growth in business R&D expenditure (1.586 in 2017 and 1.832 in 2015); that is, the government funding of R&D of other sectors, such as higher education institutions, government organisations and non-profit institutions controlled by the government which perform or provide R&D services has a more sizable effect on business investment in R&D. This can be explained by the fact that such types of funding increase the quality of R&D personnel, lead to better infrastructure supporting R&D, and raise the overall level of R&D expertise, which in turn improves the institutional framework for conducting R&D and attracts more business R&D investment. The effect of the corporate income tax rate was not of prime interest; however, based on the 2017 model results it is assessed that a 1 percentage point reduction in a corporate income tax rate leads to a 0.24 per cent increase in business-financed R&D. All estimated effects in the preferred models are significant at 0.01 and 0.05 levels.

***Thesis statement 5.* There is a strong positive association between business R&D and productivity.**

The correlation coefficient between business R&D (BERD) and productivity has been assessed at a cross-country cross-industry level (based on NACE Rev. 2 at the 2-digit level) for a number of European countries for which the relevant data were available (Table 1).

***Table 1* - The strength of association between productivity and R&D intensity in selected business industries based on cross-country data, 2017**

Business industries	Pearson correlation
1.Manufacturing industry	
1.1 High-technology:	
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.427**
Manufacture of computer, electronic and optical products	0.648***
1.2 Medium-high-technology:	
Manufacture of chemicals and chemical products	0.681***
Manufacture of electrical equipment	0.728***
Manufacture of machinery and equipment n.e.c.	0.894***
Manufacture of motor vehicles, trailers and semi-trailers	0.755***
Manufacture of other transport equipment	0.293
1.3 Medium-low-technology	0.658***
1.4 Low-technology	0.506**
2. High-tech knowledge-intensive services:	
Telecommunications	0.272
Computer programming, consultancy and related activities	0.284
Information service activities	0.443**

Note: significance level p: * < 0.10, **< 0.05, ***< 0.01.

Source: own construction.

The correlation analysis revealed a strong positive association between business R&D and productivity in medium-high technology industries (except for “Manufacture of other transport equipment”) and in medium-low technology industries based on the Eurostat high-tech classification of manufacturing industries; a medium-strong and strong positive association in high-technology industries; a lower yet medium-strong positive association for low-technology industries and for “Information service activities”; and a low and not significant correlation coefficient for other high-tech knowledge-intensive services, such as

“Telecommunications” and “Computer programming, consultancy and related activities”. A lower than anticipated correlation between the two variables in the pharmaceutical sector can be explained by the fact that in some countries, such as the United Kingdom, Sweden, Norway, Denmark and France, businesses prefer to contract out a significant part of their R&D to research organisations. As contract research may be considered as a part of intermediate consumption on national accounts, it can distort to some extent business R&D intensity indicators of those countries (since R&D expenditures by the main type of activity of the enterprise in terms of turnover are used in computation of productivity). The correlation coefficient for “Information service activities” was affected by outliers. Thus, Portugal and Iceland had a low productivity estimate related to R&D intensity, while for Belgium and the United Kingdom the productivity was significantly higher in comparison with R&D efforts of the sector. When excluding these countries the correlation coefficient increases to 0.746.

Regarding the heterogeneity in the association between R&D intensity and productivity in manufacturing industries with different R&D intensity levels, it should be noted that the strength of association is lower for low-technology manufacturing industries. This outcome is supported by the study of Ortega-Argiles, Potters, and Vivarelli (2011), who conclude that high-tech sectors are far ahead in terms of the impact on productivity of their R&D investments as regards top European R&D investors.

Therefore, considering that most commonly European countries do not differentiate R&D tax incentives by industrial sectors, the third-order effects of R&D tax incentives in the form of productivity growth may be expected primarily from sectors which have a strong positive association between business R&D expenditure and productivity.

Thesis statement 6. **Strength of institutions in a country plays an important role in the efficient implementation of R&D tax incentives.**

The cluster analysis was conducted based on the computed tax incentive implementation rates of 18 European countries, data on the generosity of R&D tax incentives – tax subsidy rates – derived from the OECD statistics, and the institutional characteristics of countries described in the Global Competitiveness Report based on the results of the World Economic Forum’s Executive Opinion Survey. Factor analysis was applied to group institutional characteristics into one factor, “strength of institutions”, which was found to be highly correlated with the tax incentive implementation rate.

Based on between-group linkages three clusters were identified (Figure 4).

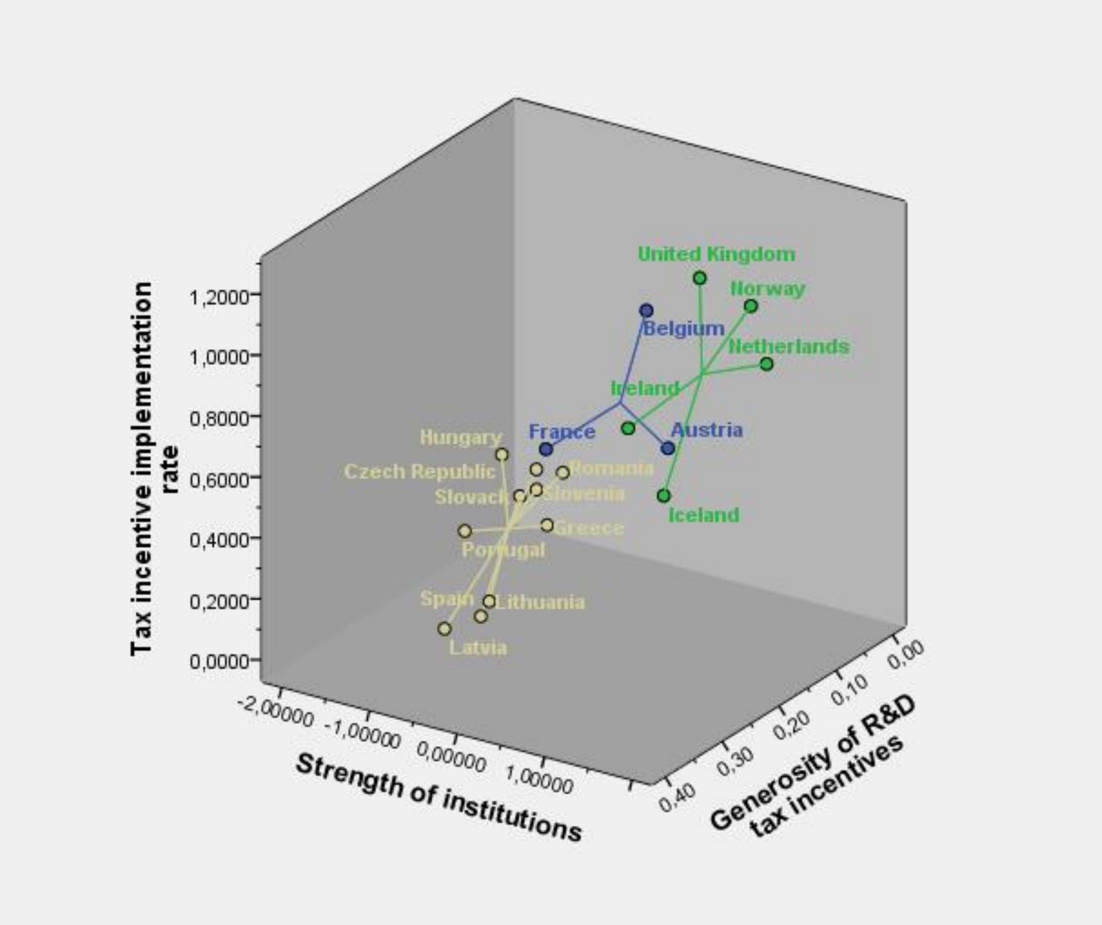

Figure 4 **– Clusters of counties based on institutional factors, generosity of R&D tax incentives, and tax incentive implementation rate**

Source: own construction

The first cluster mainly consists of the British Isles and Scandinavian countries, which have the highest tax incentive implementation rates (the mean is 0.98) and strongest positions in institutional characteristics (the mean is 5.5 in a scale from 1 to 7); the second cluster consists of Western European countries with the average TIIR at 0.80 and the mean value of 4.7 for "strength of institutions"; the third cluster has the lowest average TIIR at 0.29 and the lowest average score for institutions (3.5) and consists mainly of Central and Eastern European countries.

The analysis of variance showed that there are significant differences among the clusters in terms of TIIR and strength of institutions; however, not in terms of the generosity of R&D tax incentives. This can mean that not the generosity of R&D tax incentives is the main driver of the policy effectiveness, but the fact of how these tax incentives are implemented and used along with the institutional framework of a country. In other words, even generous R&D tax incentives may gain low popularity among businesses due to weak institutional framework in a country, which would lead to a less efficient implementation of tax incentive policy, and therefore the low effect of the tax incentive policy on firms' R&D activity can be expected.

Therefore, the institutional framework of a country should be taken into account when implementing R&D tax incentives. Strong institutions may facilitate better delivery of R&D tax incentive policy and encourage firms to use tax incentives.

Thesis statement 7. **The benchmark tax incentive implementation rates can be used in the modelling of potential additionality effects of R&D tax incentives in countries that have similar institutional characteristics but are lagging behind in terms of the efficiency of implementation of R&D tax incentives.**

While institutional parameters of countries are more stable over time, the differences in TIIRs among countries with similar institutional characteristics may be caused by specific features of the tax incentive schemes such as their simplicity, ease of use, lower compliance cost and others, which may be more easily adapted by policymakers.

Based on similarity in the institutional setting identified by cluster analysis, the benchmark European countries were chosen (Table 2), and their TIIRs were applied to countries lagging behind in terms of the efficiency of implementation of R&D tax incentive policy.

Table 2 **– Benchmark and baseline countries for TIIRs modelling**

Benchmark country	Hungary	Portugal	United Kingdom
Baseline countries	Latvia Romania Slovak Republic Greece	Czech Republic Lithuania	Norway Netherlands

Source: own construction.

The simulation analysis revealed that while the baseline countries improve their delivery of R&D tax incentive policy, all other things being equal, the average business-financed R&D in the analysed European countries may increase by 0.016 percentage points from 0.730 per cent of GDP to 0.746 per cent of GDP. Further analysis was applied to adjust the differences in TIIRs in some countries that can be caused by the design features of tax incentive schemes such as limitations in the use of tax relief. Thus, for example, if Austria were to apply similar contracting rules as in France, assuming that taxpayers have similar behavioural patterns, the average tax support would further increase up to 0.117 per cent of GDP, and the average business-financed R&D would increase to 0.750 per cent of GDP.

***Thesis statement 8.* Current practices in benchmarking and ranking R&D tax incentive schemes should be further developed and complemented by the additional design features of R&D tax incentive schemes.**

Based on the thorough review of current practices in benchmarking and ranking R&D tax incentive schemes the necessity to complement such analysis by the additional desired features of tax incentive schemes is pointed out. It is suggested that the following design features should be additionally scrutinised in identifying best practices, which would allow more comprehensive and equitable comparisons: taxability of tax relief; eligibility of certain expenditures (i.e. costs of R&D audits, qualified prototype and pilot model expenses); applicability of tax relief to future, current and retroactive investment; availability of advance approval of R&D projects; and refundability of tax relief though redemption against other taxes.

The preferable application of these design features is presented in Table 3.

***Table 3* – Additional design features for benchmarking R&D tax incentive schemes**

Design features	Content	Best practice
Taxability of tax relief	Taxable versus non-taxable	Non-taxable
Expenditures covered	Treatment of costs of R&D audits	Covered for SMEs
	Eligibility of qualified prototype and pilot model expenses	Eligible for SMEs
Applicability of tax relief based on timing of R&D expenditures incurred	Applicability to retroactive, current or future investment	Applicable to retroactive, current and future investment
Availability of advance approval for future R&D projects	Available versus not available	Available
Refundability	Cash refunds versus redemption against other taxes	Redemption against other taxes; cash refunds if the full amount was not redeemable through other taxes

Source: own construction.

The following practices of R&D tax incentives can be recommended in countries, considering their capacity to finance tax incentive schemes: providing cash refunds to SMEs, which can be justified due to their limited financing capabilities; providing cash refunds for large firms if the amount of tax incentive was not reimbursed through carry-over provisions after a certain period of time (examples are Belgium, France); providing cash refunds at a discount in case of budget constraints (can be optional, as in Spain) – such a design will incentivise large companies to conduct profitable activity at the same ensuring the recovery of their R&D expenditures; offering fiscal incentives to R&D with novelty requirement "new to the firm” or “new to the country” in countries which are lagging behind in terms of innovation, meanwhile, adoption of a patent box regime in such a country will incentivise the creation of high-quality patented inventions.

Thesis statement 9. **Developed methodological framework of the B-index for loss-making firms and approaches to TIIR computation will allow increased cross-country comparability of the estimates of the R&D tax incentives’ effectiveness and the efficiency of their implementation.**

To demonstrate the potential sources of discrepancies among studies, the tax price of R&D was modelled according to different approaches to its computation applied in R&D tax incentive evaluations. The results showed that the tax price of R&D significantly varies based on the methodology used, which may further affect estimates of policy effectiveness.

To improve cross-study comparability of the estimates of the R&D tax incentives’ effectiveness, an approach to R&D tax price computation was developed to account for carry-forward provisions (i.e. modelling carry-forwards for deductible R&D expenses; discounting tax credits based on the average period of their recovery) and cash refunds (discounting cash refunds of R&D tax credits where applicable).

According to it, the following formula was suggested for the computation of R&D tax price:

$$R\&D^{tax\,price}{}_i = p_t^K \times \frac{1 - \tau_i(1 + r_i)^{-l_i} - \lambda_{mi}\sum_{m=n}^{k} c_i(1 + r_i)^{-m_i}}{1 - \tau_i(1 + r_i)^{-l_i}}, \tag{4}$$

where $R\&D^{tax\,price}{}_i$ is the tax price of R&D in a country i; p_t^K – purchase price of R&D; τ_i – corporate income tax rate; r_i – real interest rate; c_i – tax credit rate; l_i – average period of returning to profit; $m = [n : k]$ – consecutive years from n to k of recovering tax credits through carry-forward provisions; λ_{mi} – constant probability of recovering tax credits in years m.

The constant probability of recovering tax credits in years m may be computed based on the average number of years required for their recovery. The following formula may be applied:

$$\overline{T_{c_i}} = \frac{\overline{TC_i}}{P_{before\,tax_i} \times (1 - \tau_i)} \quad , \tag{5}$$

where $\overline{T_{c_i}}$ – the average period of recovering tax credits in a country i; $\overline{TC_i}$ – the average size of tax credits; $\overline{P_{before\ tax_i}}$ – the average profit before income tax.

The data required for computations may be derived from tax filings of firms benefitting from R&D tax incentives. The developed methodology will allow more precise estimation of the tax price of R&D for loss-making firms and will lead to more reliable estimates of the effectiveness of R&D tax incentives.

The comparability of the introduced measure of TIIR can be improved by:

– calculating the weighted tax subsidy rates for European countries where such data are not currently available, especially those which impose limitations on the use of R&D tax incentives;

– estimating R&D tax expenditures on an accrual basis (accrual estimates allow disregarding the differences in TIIRs that may arise due to better economic conditions of firms affecting their profitability status);

– reporting of R&D expenditure on net of tax basis (will better reflect the size of tax stimuli and will lead to more precise estimates of TIIRs);

– aligning tax incentives used for the computation of the B-index and for the estimating the amount of tax support of R&D (tax incentives that are not modelled in the B-index should be excluded from the amount of tax support for the purpose of calculating TIIRs).

To ensure the cross-country comparability of R&D tax incentives evaluations, it is recommended to compare with caution studies that make estimates of increase in qualifying versus total R&D expenditure and evaluate intensive versus total margin effects of R&D tax incentives; meanwhile, studies evaluating the effect of policy change versus the overall effect of R&D tax incentives should not be compared.

General conclusions and recommendations

The dissertation provides an overview of R&D tax incentive policies in European countries. It demonstrates that different policy designs are used to achieve state objectives, such as growth of business R&D investment, stimulating cooperation between industry and public research institutions and universities; and encouraging patenting activity.

The decisions on adopting R&D tax incentives and selecting their generosity should be consistent and properly developed. The decision-making model presented in Chapter 1, based on the historical experience of the adoption and changes in the generosity of tax incentive schemes, can guide policymakers in this process.

The direct additionality of tax incentives should be a central question in evaluations of policy effectiveness. Cross-country analysis conducted in Chapter 2 for 18 European countries provided evidence of positive first- and second-order effects (additional business-financed R&D is estimated at an average of 1.63 in 2017 and 1.08 in 2015; and on average 32.3 and 20.5 per cent of total patent applications were due to R&D tax incentives in 2017 and 2015, respectively). Furthermore, the strong- and medium-strong positive correlation coefficient between business R&D and productivity estimated at a cross-country cross-industry level for a set of European countries allows to suppose the existence of positive third-order effects of tax incentives for these industries.

The cluster analysis coupled with factor analysis of institutional characteristics of European countries conducted in Chapter 3, showed that countries with stronger institutions (based on the factor score) have higher TIIRs. Therefore, it was concluded that strong institutions may facilitate better delivery of R&D tax incentive policy.

Developed methodological framework of the B-index for loss-making firms and approaches to TIIRs computation in Chapter 3 will allow increased cross-country comparability of the estimates of the R&D tax incentives' effectiveness and the efficiency of their implementation, and will form a basis for conducting more reliable analysis of tax incentives attractiveness.

Based on the suggested improvements in methodological approaches, further research may provide additional insight on firms' responses to tax stimuli and would allow identification of the best practices grounded on empirical results.

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Workshops and conference presentations:

1. “Heterogeneity in implementation of R&D tax incentive policy: The role of institutional factors”. 3rd RICE PhD Seminar Sustainable Business and Economy, University of Public service, September 2022, Budapest, Hungary.
2. “R&D tax expenditures in the EU countries: On the way to achieving consistency in public administration”. The Conference “Critical Rethinking of Public Administration” organised by Doctorates' Council of the Ludovika – University of Public Service and Public Administration Department of the Association of Hungarian PhD and DLA Candidates, Ludovika – University of Public Service, 8 April 2022, Budapest, Hungary.
3. “R&D tax incentive implementation rate: a novel approach for analyzing attractiveness of R&D tax treatment”. 2nd RICE PhD Seminar “European business and economy”, National University of Public Service, 24 September 2021, Budapest, Hungary.
4. “Reshaping R&D tax incentive policy in terms of international tax competition”. 1st RICE PhD Seminar “Economic challenges of 2020”, National University of Public Service, 4 September 2020, Budapest, Hungary.
5. “Methodological issues of analyzing attractiveness of R&D tax incentives in cross-country comparisons”. International Scientific Conference “The Challenges of Analyzing Social and Economic Processes in the 21st Century”, 7-9 November 2019, University of Szeged, Szeged, Hungary.
6. “Reporting on R&D tax expenditures in OECD countries”. XI Nemzetközi Tudományos Konferencia 'Mérleg és Kihívások', 17-18 October 2019, Lillafüred, University of Miskolc, Hungary.
7. “R&D tax incentives in terms of international tax competition”. Academic conference “Intelligent specialization to enhance innovation and competitiveness”, Széchenyi 2020 program framework (EFOP-3.6.1-16-2016-00013) under the European Union project, 27 November 2018, Székesfehérvár, Corvinus University, Hungary.
8. “Tax incentives for encouraging R&D activities”. Challenges in National and International Economic Policies workshop supported by the European Association for Comparative Economic Studies”, 23-24 March 2017, University of Szeged, Hungary.

Summer schools:

1. “Quantitative Methods for Public Policy Evaluation”, Barcelona Graduate School of Economics (on-line course), 2021.
2. “Introduction to Structural Equation Modeling: Confirmatory Factor Analysis with Mplus”, The 8th GESIS Summer School in Survey Methodology, 2019, Cologne, Germany.
3. “Introductory Econometrics”, SIdE Italian Econometric Association, 2019, Bertinoro, Italy.
4. “PhD Summer School in Circular Economy”, EIT Raw Materials, 2018, Diest, Belgium.