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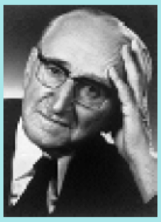



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The Implementation of Research and Development Policy in European and Asian Countries

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Abstract

Research and development (R&D) policy has to fulfil a central role in innovation policy since it consists of government sector measures that support R&D in order to initialise and promote innovation. The authors of this article discuss first the theoretical reasoning for government sector intervention in R&D processes. The empirical study examines the level and structure of government sector resources and expenditures for R&D policy in EU member states (including Estonia), countries closely associated with the EU, China, Japan and South Korea. The aim of the article is to compare the position of these countries on the basis of R&D policy implementation from the aspect of resource and expenditure supply. In order to achieve the aim, the following research tasks are tackled: on the basis of research literature, the necessity, essence, measures and anticipated outcomes of R&D policy are explained to create the theoretical base for the empirical study; on the basis of the empirical analysis, an assessment on the international position of R&D policy implementation in several new EU member states and Asian countries is conducted. The data used in the empirical analysis is gathered from Eurostat and OECD databases

Keywords: market and system failures, R&D policy, EU, Estonia, South Korea

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The Implementation of Research and Development Policy in European and Asian Countries

Introduction

In order to promote innovation as one of the most important development factors of a country, a complex and efficient national innovation system must be developed. The integrity and harmonious functioning of the national innovation system must be guaranteed by innovation policy, which intermediates the relationship between organisations dealing with innovation (firms, government agencies and NGOs) and institutions (both formal and informal), but also integrates the parts of different policies directed to innovation to a single innovation policy.

The central role in innovation policy development is executed by research and development (R&D) policy, which represents the major complex of government sector measures to initiate and promote innovation. When planning the policies of other fields (e.g. education, labour market, budget and taxes), the interrelationship with R&D policies and activities must be taken into account. The creation of anything new is always connected with uncertainty, with a risk of no positive results, irrespective of the expenses made. The incoordination of R&D policy with other policies, i.e. deficiency of the innovation system, can limit the results of R&D activities in the economy and economic growth; also, the productivity increase or improvement in competitiveness may not be achieved to the desired extent. That is why government sector R&D policy is not solely responsible for the innovation success of a country, but the importance is large enough to consider it as a separate research object.

In the current article, the levels and dynamics of R&D policy resource supply and costs will be analysed by comparing EU member states, countries closely associated with the EU and three Asian countries. As above, we will present the comparable role of R&D policy in innovation systems of different countries. It should be taken into account that different countries (small and large, highly developed and in the transformation phase, with open and closed economies, in different development stages) have different innovation policy objectives and measures to achieve them (Czarnitzki, Bento 2010; Hewitt-Dundas, Roper 2010). Still, R&D policy is developed in more general institutional conditions. For instance, in countries with a majority election system the structure of the state budget is shifted towards a smaller share of public services (including scientific research) and a larger share of social transfers (Persson et al. 1997; Persson, Tabellini 1999; Persson et al. 2000). Kim (2011) shows that R&D policy (financing) decisions are influenced by the specifics of a state political system – the location of a state in the political space, the dimensions of which are presidential versus parliamentary system; majority versus proportional election system; federal versus unitary government system; a parliament consisting of one or two chambers; number of parties in the parliament. All of those qualitative aspects must be taken into account when interpreting the results of quantitative comparative analysis of R&D policies in different countries.

The goal of the article is the comparable assessment of R&D policy implementation in EU member states, countries closely associated with the EU and three Asian countries in respect of R&D policy implementation from a resource supply and cost aspect. In order to achieve the research goal, the following research tasks are tackled:

- on the basis of scientific literature the necessity, nature, measures and expected results of R&D policy in a country are identified;
- through empirical analysis an assessment is given to the international position of Estonia and some other countries (South Korea and Germany) in implementing R&D policy among the countries in scope.

The results of the research help to understand the differences of R&D policy development in different countries, taking into account theoretical approaches and international experience.

1. Theoretical Questions of Research and Development Policy Interventions

Firstly, it is necessary to give a theoretical overview of the justification of government sector intervention in R&D processes. Generally, the intervention of the government sector is considered to be justified in the case of market and system failures. The government sector should intervene with adequate measures on a scale, which is necessary to overcome the abovementioned failures. At the same time, the government sector should avoid overreaction to failures that will lead to the distortion of market processes and not provide state aid in the shade of R&D policy.

1.1. Elimination of Market Failures

Market failures in R&D activities have been researched for decades (Dasgupta, David 1994) and they appear in several different forms. In the following, the main market failures in R&D activities will be highlighted. Firstly, the nature of invention and innovation has to be considered. For over fifty years, the question whether R&D outcomes are more public than private good in nature has been attended (Nelson 1959; Arrow 1962). The consumption of R&D outcomes has generally no rivalry, i.e. the invention or innovation can be used parallelly and the utility can be acquired by an endless amount of users without changing their nature (see Romer 1990; Grossman, Helpman 1991; Aghion, Howitt 1992). However, market competition between users of R&D results remains – the profit earning capacity of innovation or invention for the first marketer decreases remarkably after others apply it. Thus, for the owner of new product, services, production technology, etc. it is very important somehow to exclude unentitled persons (competitors) from using its R&D work results, i.e. the protection of intellectual property is needed. As the protection of intellectual property is often difficult and expensive, the economic rationality of its application should be considered. Therefore, the intervention of the government sector and the necessity of R&D policy come from the fact that due to the absence of competitive rivalry in use, innovation is not a pure private good and firms cannot afford excluding others from the use of their R&D work results. However, for several cases government sector intervention cannot be justified purely for excluding market competition because of the absence of rivalry in the use of the R&D results; better reasoning is needed.

For the society as a whole it is useful to emphasise the public good nature of research work results and involve as many organisations (firms and institutions) and members of the society as quickly as possible in the consumption of the R&D results. Thus, the government sector should fund research activities that create public goods. As the result of public institutions' R&D activities, knowledge available to all interested parties is created (Edquist 2006). Public sector R&D activities are financed with an objective to support innovation from research offered as a public good mainly in private firms, but also in public sector institutions. It is expected that fundamental research at universities or scientific research establishments lead to discoveries, the value of which is recognised by firms that apply this new knowledge in implementing innovative projects (Pavitt 2006). The influence of public sector R&D activities on private sector R&D investments and productivity was assessed with macroeconomic models a few decades ago (Levy, Terleckyj 1983).

The practical usefulness of fundamental scientific research is very difficult to assess (Greenberg 1967; Sherwin, Isenson 1967). Normally it takes years or decades until the results of fundamental research are being practically applied (Gellman Associates 1976; Adams 1990; Mansfield 1991, 1998; Branstetter, Ogura 2005), whereas their application in practice and usefulness develop in the interrelation of many factors (Rogers, Bozeman 2001; Bozeman, Rogers 2002). The profitability of fundamental scientific research is therefore very unsteady. This means that the results of fundamental research can only be offered to society commissioned by public sector organisations and funded from the state budget.

Development work has less characteristics of a public good. The R&D activities conducted by firms are more development work than fundamental research: the objective is to find application possibilities for new knowledge so the profit of the firm would increase (Edquist 2006). That is why funding by the government sector is justified only exceptionally and in a limited amount. Besides supporting development work with resources, the government sector should consider applying intellectual property protection measures in order to constrain the usage of results as public goods. The elimination of market competition and the creation of private monopoly with the help of the government sector are justified only in areas where it is necessary to stimulate firms to provide funds for research activities. In addition, it should be examined whether government sector R&D subsidies increase (supplement) the R&D costs in firms or replace (substitute) them (Leyden, Link 1991; Lach 2002). Government sector R&D costs increase total social R&D costs when the government sector support influences the private sector to allocate R&D funds to projects that without the support would not be profitable (Klette et al. 2000; Wallsten 2000; Jaffe 2002; Tokila et al. 2008). However, the threat that the government sector support will substitute private sector R&D costs emerges inevitably in cases where the private sector has resources but they are more expensive than those offered by the government sector (Jaffe 2002; Blanes, Busom 2004). It is difficult to assess the impact of R&D activities for country as a whole since some firms get them and others do not (Hujer, Radic 2003). A lot of empirical research has been directed to finding out the effect of government sector R&D support on private sector R&D expenditure. These will be reviewed in the second part of the current research.

Generally, research has a positive externality (transfer of knowledge), which is revealed both between research institutions and from research institutions to organisations (firms and institutions) that apply the new knowledge (see Romer 1990; Audretsch et al. 2002). In the case of fundamental research, the international transfer of knowledge must be accounted for (Funk 2002). The private utility of R&D activities to organisations creating new knowledge is much smaller than the social utility because of positive externalities and thus there would be an under demand for R&D (see Griliches 1988). That is why the task of the government sector is to bring the demand for research at the social utility level by applying R&D policy measures.

Development work usually takes place in the organisation implementing the results, which is why it does not have such important direct externalities. In respect of development work, the government sector has a task to promote more externalities (transfer of knowledge and technical solutions). By giving the results of development work the nature of a public good, the government sector has a responsibility to promote development work in firms in order to hedge risks connected with R&D. Of course, it should be checked whether government sector subsidies for firm-level R&D will liquidate market failure or, on the contrary, serve as the distortion of competition (Klette et al. 2000).

Research is characterised by important informational failures (the asymmetry of information) between market participants and by large sunk costs that constrain market exit, which in turn prevents private firm activities in R&D (Carboni 2011). Private firms do not risk making sufficient long-term investments in research due to the uncertainties of R&D results (Dosi 1998). The task of the government sector is to reduce these risks by promoting the creation of inventions and scientific discoveries, but also by promoting the wide consumption of innovations as public goods.

A market failure is also a situation where a firm does not have sufficient resources for innovation (Martin, Scott 2000). In order to promote innovation, the government sector tries to fulfil that resource shortage with its support.

To overcome market failures, the main policy measures related to R&D work have traditionally been subsidies from the government sector budget to create new knowledge and the protection of intellectual property by laws (Edquist et al. 2004). In addition, the form of government sector intervention should proceed from the nature and impact scope of market failures, in order not to excessively reduce government sector's initiative and responsibilities in the design and implementation of development measures.

1.2. Eliminating System Failures

When promoting R&D work the government sector must help to eliminate system failures that prevent research results reaching the phase that is necessary for practical implementation. Overcoming system failures that reduce the impact of R&D means developing the national innovation system in such a way that all parties involved have good cooperation in promoting R&D activities and implementing research results. According to the OECD (1997), system failures are revealed in the following: lack of cooperation between different parties in the innovation process, incompatibility of public sector organisations' fundamental and applied research, inefficient activities of technology transfer organisations and deficiencies in information distribution. In case those failures are not prevented or treated, the resources meant for R&D work will not have the expected effect in guaranteeing economic development. In order to overcome system failures, policy instruments should be directed to creating missing components of the system, developing cooperation relationship and correcting mistakes made in system development. (Metcalfe 2005) That approach is supported by the position (Arnold 2004) that the government sector cannot be limited to financing only (traditional) fundamental research, but must guarantee the functioning of the whole innovation system and also eliminate or reduce occurring failures.

System failures restraining the development of R&D work and the usage of R&D outcomes can be classified as follows (Arnold 2004):

- capability failures – the incapability of research institutions to act derived from bad management, lack of competence, weak study capabilities and other deficiencies;
- failures in institutions – the stiffness of the activities of organisations (universities, research institutes, patent offices, etc.) and thus the incapability to adjust to environmental changes;
- network failures – problems in the relationships of innovation system parties, which are characterised by the shortage of relations or their insufficient quality, the incapability to apply new knowledge and tangling in morally aged technology;
- framework failures – deficiencies in legal institutions, intellectual property protection, health and safety requirements and other background conditions, including social values;
- policy failures (Tsipouri et al. 2008) – deficiencies in the government related to R&D policy development, coordination with other policies and the assessment of policy outcomes, etc.

In order to overcome system failures that reduce R&D work efficiency and hinder innovation, the government sector must develop an evaluation system for research institutions, systematically direct research institutions to fulfil tasks important for economic development, create networks to spread new knowledge and implement counselling programs, but also improve regulatory mechanisms (e.g. laws) that are important for development of R&D activities. Still, it should be taken into account that the government sector intervention should be in accordance with the nature and impact of the system failure. Also, the resources should be used efficiently and regulations should not reduce the private sector's initiative that is needed to develop R&D activities. When considering the intervention by the government sector, different failures in the work of public sector institutions and organisations must be considered (e.g. the instability of the political decision process, the increase of bureaucracy, decision makers' irresponsibility for the results, the possibility of corruption, etc.).

The place of institutions dealing with R&D work among organisations belonging to the national innovation system can be defined as follows (OECD 1999):

- government organisations (at local, regional, state and international level) that develop general R&D policy directions;
- bridging organisations, such as scientific councils and societies that are intermediaries between governments and researchers;
- private firms and research institutions that are funded by firms;
- universities and other connected institutions that create new knowledge and skills;
- other public and private organisations that have special R&D policy roles in the national innovation system (open laboratories, technology transfer institutions, common research and exploratory institutes, patent offices, educational institutions, etc.).

The diversity of R&D activities suggests that when designing public R&D policy, all above-mentioned institutions should be directed to cooperate for achieving common goals, i.e. an institutional environment favouring interactions between organisations should be created. Institutions are defined as the collection of habits, norms, routines, practices, rules or laws that regulates relationships and interactions between individuals, groups and organisations (Edquist, Johnson 2000). The importance of institutions in guaranteeing the development of innovation is emphasised by Klun and Slabe-Erker (2009). Formal and informal institutions, fundamental and supportive institutions, strict and soft institutions, deliberately and spontaneously created institutions must all be taken into account (Edquisti, Johnson 2000).

The main components of the institutional environment influencing organisations are the legal system, norms, routines, standards, etc. Different institutions can support and strengthen each other, but they can also be in conflict or restrain one other. (Edquist 2006).

When developing the central element guaranteeing the functioning of the national innovation system, the R&D policy, the size of organisations (firms and institutions) must be taken into account. In the case of the dominance of small firms, an innovation system and R&D policy, which takes into account their specifics, must be developed (Reinkowski et al. 2010).

1.3. Considering the External Sources of Knowledge in R&D Policy

When designing R&D policy, it should be considered that R&D activity is not the only engine for the development of state innovation. Mainly small countries should consider whether and in which areas new knowledge is created and to what extent its procurement from other (outside) sources should be supported. Coe and Helpman (1995) and Keller (2004) emphasise the importance of using international channels in procuring new knowledge especially in the context of small open economies. Firstly, imports are emphasised as the (outside) source of new knowledge promoting national development (Coe, Helpman 1995), thus the structure of imports should be deliberately shaped to favour innovation. In the last decade exports have also been emphasised as an important source of learning from foreign experience (Delgado et al. 2002; Baldwin, Gu 2003; Alvarez, Lopez 2006; Greenaway, Keller 2007). Still, the attitude towards foreign direct investments as the source of the procurement of new knowledge has been controversial: in studies conducted by Braconier et al. (2001) and Grünfeld (2002) the transfer of knowledge from foreign direct investments was not discovered, however it was discovered in studies by van Pottelsberghe, Lichtenberg (2001) and Damijan et al. (2004).

The usage of an external source of new knowledge has to be combined in the best way that the state is capable to create new knowledge in the R&D system. Thus, when designing the R&D policy, the need to integrate R&D activities with the national innovation system must be taken into account.

In small open economies the importance of using external sources of knowledge does not reduce the importance of promoting R&D activities in order to guarantee economic development. Cohen and Levinthal (1989) and especially Griffith et al. (2004) mention two objectives for R&D development: on the one hand the creation of new knowledge and on the other hand the development of the absorption possibility of new knowledge from external sources. Diao et al. (1999) also note the importance of absorbing new knowledge from foreign sources to small open economies. The final objective is to improve the innovation performance of firms, but in a small country more attention has to be directed to new knowledge absorption capability development. Verbič (2011) notes in the Slovenian case the share of foreign countries as the source of the development of technology.

The systematic development of R&D policy to eliminate system failures must create favourable conditions to promote innovation in the public sector. At the same time, several application problems have to be solved.

2. Comparative Analysis of Research and Development Policy Implementation

2.1. Data and Variables Used in the Analysis

Diverse and complicated issues of government sector interventions in R&D processes presented in the previous section of the article signify the broad extent of alternatives for policy decisions. Each country forms its own R&D policy corresponding to historical traditions, situation and long-term goals of the development. Increasingly, the EU influence has to be taken into account. As result, the content of R&D policy is qualitatively different in different countries. The same value of resources supply or expenditures to R&D activities can represent qualitatively different policy measures. On the one hand, this is a limitation for quantitative comparable analysis which has been taken into account by interpretation of results. On the other hand, through quantitative comparison we can highlight the differences in the level and structure of the resources supply and expenditures of R&D policy in different countries helping us to understand the qualitative differences of this policy between countries.

In the current study, the government sector position of some European and Asian countries in R&D policy implementation among the investigated sample of countries will be assessed as there is a database created on common principles. Therefore, the results of countries analysed are directly comparable.

In total, 35 countries are used in the analysis (27 EU member states, Croatia, Turkey, Iceland, Norway, Switzerland, South Korea, China and Japan). The statistical data used is from the Eurostat online database and OECD Statistics database.

The results of comparative analysis of R&D policy implementation are more thoroughly analysed in three countries: an “old” EU member country Germany that is internationally recognised for its R&D achievements; Estonia as a successful “new” member country where efforts are made to foster R&D policy; South Korea as an Asian country that has achieved remarkable development success. In appendix, an aggregated assessment of R&D policy implementation for all analysed countries is given.

In the current study, data from six years is applied in order to follow the dynamics of different policy aspects. All variables in analysis have been taken from the years 2000, 2002, 2004, 2006, 2008 and 2010. This way the whole decade is covered by the data.

Many theoretical approaches and empirical research (European Commission 2003; Falk 2004; OECD 2005; Koch et al. 2007; Manjón 2010) have highlighted several variables that describe government sector R&D policy and which can be used to assess the level and structure of R&D policy in different countries. In the current study, the following variables will be used to comparatively assess government sector R&D activities in the investigated sample of countries (see tables 2.1 and 2.2). The tables also note previous research where given variables have been applied before. Analysing different variables separately would give fragmented results. In the current analysis, data describing government sector R&D activities are considered as a whole complex, taking into account the interconnections of variables.

One of the goals of R&D policy is to develop R&D activities carried out by the public sector. This aspect is described by the first set of variables (see table 2.1). The first four variables describe R&D activities carried out in the public sector. For those variables it must be taken into account that not all R&D expenditure in education, and especially in the higher education sector are financed by the government sector – some of the funding is provided by the business and non-profit sectors, but also from the external sources. Therefore, it is important for each country to highlight those variables that describe R&D expenditure funded by the government sector of that country (variables 5-6). Variable 7 describes the government budget – more specifically its share in R&D financing. The last two variables in table 2.1 describe the share of public sector R&D personnel in total employment, which describes the supply of work force in public sector R&D activities.

Table 2.1. Variables describing public sector R&D activities

No	Abbreviation	Variable description	Source
1	GOVgdp	Government sector R&D expenditure (% of GDP)	European Commission 2003; Falk 2004; OECD 2005; Koch et al. 2007; Manjón 2010
2	GOVshr	Share of government sector R&D expenditure (% of total R&D expenditure)	European Commission 2003; Sanchez, Bermejo 2007
3	HESgdp	Higher education sector R&D expenditure (% of GDP)	Falk 2004; OECD 2005; Koch et al. 2007; Manjón 2010
4	HESshr	Share of higher education sector R&D expenditure (% of total R&D expenditure)	European Commission 2003; Sanchez, Bermejo 2007
5	GOVtoGOV	Government sector R&D financing from the government sector budget (% of GDP)	OECD 1999; European Commission 2003
6	GOVtoHES	Higher education sector R&D financing from the government sector budget (% of GDP)	Added by the authors
7	GBAORD	Share of government budget appropriations or outlays on R&D in government sector total costs (%)	European Commission 2003; OECD 2005; OECD 2007; Sanchez, Bermejo 2007
8	empGOV	Share of government sector R&D personnel in total employment (% according to data converted to full time equivalents)	Manjón 2010
9	empHES	Share of higher education sector R&D personnel from total employment (% according to data converted to full time equivalents)	Manjón 2010

Source: compiled by the authors.

The second important area of R&D policy is supporting business sector R&D activities. Variables describing public sector support to private sector R&D activities are given in table 2.2. In this research, two business sector R&D financing indicators are used that measure the level of government sector financial support to business sector R&D activities. When analysing the government support for business sector R&D in European countries, data from Community Innovation Survey (CIS) study could also be used. However, this data is not available for Asian countries and thus these variables are left out of the analysis.

Table 2.2. Variables describing public sector support to business sector R&D activities

No	Abbreviation	Variable description	Source
1	GOVto BESgdp	Business sector R&D financing from the government sector budget (% of GDP)	Falk 2004
2	GOVto BESshr	Share of government sector financing in business sector total R&D expenditure (%)	OECD 2005; Koch et al. 2007
*	funPUB	Share of innovative enterprises that received any public funding (% of total innovative enterprises)	CIS; Koch et al. 2007; Nina 2009; Manjón 2010
*	funLOC	Share of innovative enterprises that received funding from local or regional authorities (% of total innovative enterprises)	CIS; Manjón 2010
*	funGMT	Share of innovative enterprises that received funding from central government (% of total innovative enterprises)	CIS; Manjón 2010
*	funEU	Share of innovative enterprises that received funding from EU (% of total innovative enterprises)	CIS; Manjón 2010

* Variable is not used in the current analysis
Source: compiled by the authors

2.2. Results of the Empirical Analysis

Table 2.3 shows the statistical parameters of variables describing public sector R&D activities and the level of government sector support for business sector R&D activities. The indicators are centred for each year to eliminate the common trends – the data characterises for each year the difference of country value from average value in the year observed (i.e. the standard deviation). In the table, the indicators' average values of six years observed are presented.

Table 2.3 indicates that the values of variables for countries vary remarkably, in both absolute (the difference between minimum and maximum levels) and relative terms (the relationship of standard deviation to mean).

Table 2.3. Statistical characteristics of variables describing public sector R&D activities and the level of government sector support for business sector R&D activities[1]

Variable	Mean	Standard deviation	Min value	Max value	Value in			Difference from mean (in standard deviations)		
					Estonia	South Korea	Germany	Estonia	South Korea	Germany
GOVgdp	0.21	0.12	0.03	0.63	0.14	0.37	0.36	-0.60	1.34	1.25
GOVshr	17.79	11.59	0.99	61.12	14.80	12.51	13.95	-0.26	-0.46	-0.33
HESgdp	0.36	0.20	0.05	0.82	0.45	0.31	0.44	0.44	-0.23	0.38
HESshr	26.40	12.25	3.79	55.61	44.56	10.61	16.76	1.48	-1.29	-0.79
GOVtoGOV	0.24	0.38	0.02	2.37	0.11	0.35	0.32	-0.34	0.29	0.21
GOVtoHES	0.28	0.17	0.03	0.62	0.35	0.23	0.36	0.39	-0.32	0.46
GBAORD	1.32	0.56	0.41	2.92	1.33	2.92	1.75	0.01	2.85	0.75
empGOV	0.16	0.10	0.02	0.49	0.14	0.08	0.21	-0.21	-0.74	0.55
empHES	0.32	0.15	0.03	0.70	0.41	0.21	0.28	0.60	-0.70	-0.23
GOVtoBESgdp	0.06	0.04	0.00	0.15	0.04	0.13	0.10	-0.49	1.84	0.93
GOVtoBESshr	7.52	6.37	1.25	34.99	8.15	5.92	5.40	0.10	-0.25	-0.33

The Estonian, South Korean and German position in public sector R&D activities and in the level of government sector support for business sector R&D activities can be seen in three last columns of table 2.3 and in figure 2.1. In the figure, the difference between minimum and maximum values (in standard deviations) and Estonian, South Korean and German mean value for each indicator is given. The figure shows that the position of Estonia is the best for the share of higher education sector R&D expenditure in total R&D expenditure (*HESshr*). However, the position of South Korea and Germany is the worst for this variable. The position of Estonia is the worst for government sector R&D expenditure (*GOVgdp*), where the position of Germany is the best. The position of South Korea is the best for the share of government budget appropriations or outlays on R&D in government sector total costs (*GBAORD*).

[1] Values have been calculated as the mean of six years (2000, 2002, 2004, 2006, 2008 and 2010).

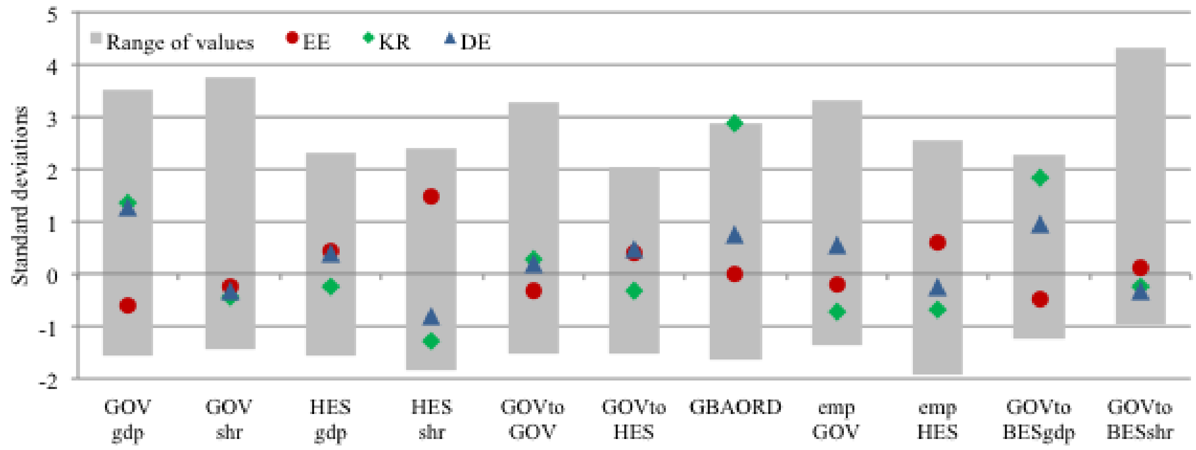

Figure 2.1. Estonian, South Korean and German position among variables describing public sector R&D activities and the level of government sector support for business sector R&D activities

Figure 2.1 indicates that according to variables describing higher education sector R&D financing, the share of higher education sector R&D personnel and the share of government sector financing in business sector total R&D expenditure, Estonia holds a higher position than the countries' average. For the rest of the variables describing public sector R&D activities and the level of government sector support for business sector R&D activities, Estonia has average or lower than average values. This indicates that the main contribution of innovation promotion in Estonia is expected from the higher education sector.

South Korea holds a higher position than the countries' average according to variables describing government budget appropriations or outlays on R&D, government sector R&D financing and the business sector R&D financing from the government sector. This indicates that in South Korea the main contribution of innovation promotion is expected from the government sector. Germany has higher than average position according to seven out of eleven variables and both higher education and government sector are seen as contributors of innovation.

The results of the comparison of R&D policy of countries on the base of eleven variables are controversial and difficult to generalise due to a large number of variables and internal correlations between variables. Approaches to compress the information through constructing a small number of complex indexes of R&D policy with the help of deterministic methods (through weighing and summarising variables' values) cannot be successful because these methods do not take into account the correlations between variables. Therefore, we have to use multiple statistical analysis methods to reduce the number of R&D policy indicators without significant information loss.

Subsequently, to bring out the factual dimensions of R&D policy activities, principal component analysis is conducted with the variables describing public sector R&D activities and the level of government support for business sector R&D activities. For the component analysis, the data of 210 observations (35 countries in six years) is used and the data has been standardised across years. The results of component analysis (table 2.4) show the structure of public sector activities promoting and supporting R&D. Component analysis is based on the internal connections in the set of variables, including the connections between the areas of public sector R&D activities and support measures.

Table 2.4. Component analysis in the set of variables describing public sector R&D policy

	K1 Level of higher education sector R&D financing	K2 Level of government sector R&D financing	K3 Level of business sector R&D financing by the government sector
HESgdp	**0.96**	-0.03	0.06
GOVtoHES	**0.94**	0.01	0.07
empHES	**0.80**	0.10	-0.18
GOVshr	**-0.70**	**0.45**	-0.21
GBAORD	**0.67**	0.32	0.38
GOVgdp	0.10	**0.94**	0.22
GOVtoGOV	0.09	**0.93**	0.27
empGOV	-0.03	**0.87**	-0.17
GOVtoBESgdp	0.31	0.07	**0.86**
HESshr	0.12	**-0.45**	**-0.64**
GOVtoBESshr	**-0.49**	-0.19	**0.49**
Component eigenvalue	3.92	3.14	1.51
Cumulative variance explained	35.62	64.19	77.90
Significance of Bartlett test	0.00		
KMO	0.69		

Rotation method: Varimax

The component analysis covering the indicators describing government sector R&D policy highlighted three independent (non-correlated) synthetic complex indicators (components) describing the internal structure of the variables. As a result of component analysis the number of variables describing public sector R&D policy decreased more than 70% (i.e. from 11 to 3), but less than 25% of the information (variation) included in initial variables set was lost (77.9% of the variance of initial variables is explained through synthetic components).

Explaining the nature of synthetic components and giving adequate names for the new indicators is a complicated task. In the current study, the method applied by Karu and Reiljan (1983) is used to explain the nature of the components.

With the first component (K1) three variables that describe higher education sector R&D funding and the share of higher education sector R&D personnel in total employment are closely correlated. In addition, variables that describe government budget appropriations or outlays on R&D and the share of government sector R&D expenditure in total R&D expenditure are strongly correlated with the given component. In the case of the last variable a reciprocal association exists that explains the crowding out effect of higher education sector R&D funding by government sector R&D funding. The nature of the first component is described as “level of higher education sector R&D financing”, whereas the level of funding also affects the possibility of employing R&D personnel.

With the second component (K2) three variables that describe government sector R&D financing and the share of government R&D personnel in total employment are strongly associated. With the given component, the variables *GOVshr* (the share of government sector R&D expenditure in total R&D expenditure) and *HESshr* (the share of higher education sector R&D expenditure in total R&D expenditure) are weakly associated. The association with *HESshr* is negative, which indicates the substitution of government sector R&D financing with higher education sector R&D financing. This component is characterised by the name “level of government sector R&D financing”.

With the third component (K3) two variables that describe the level and share of government sector financing in business sector R&D are correlated. The variable *HESshr* (the share of higher education sector R&D expenditure in total R&D expenditure) has a negative correlation with the component. The nature of the given component is best explained by the name “level of business sector R&D financing by the government sector”.

Component scores describe each country in the analysis. As each country is represented in the sample with data from six years, there are six component scores for every country. In order to compare countries, they are characterised with the mean of six component scores (see appendix 1). Component scores indicate that the structure of government sector R&D policy varies remarkably through countries – countries emphasise different R&D policy areas. Figure 2.2 illustrates the results of the international position of Estonia, South Korea and Germany.

In figure 2.2 Estonian, South Korean and German average positions among the analysed countries are shown using three complex indicators (components) that explain government sector R&D policy in a way that the difference from the mean value and the distance from the extreme values of the investigated country sample can be seen. While in general Estonia is below the average level of R&D policy implementation, Estonian activities can still be considered balanced – in the case of all components the difference from the average level is smaller than the distance from the extreme values. According to all components, the performance of South Korea and Germany is above the average level.

According to component K1 (the level of higher education sector R&D financing), the Estonian average component score is higher (by 0.44 standard deviations) than the average of analysed countries and Estonia is situated in the first half among all countries analysed (11^{th} position out of 35). Thus, the government sector finances higher education sector R&D to a higher level than the countries’ average. The component scores for South Korea (0.26) and Germany (0.39) are almost equal to Estonia and the countries are ranked 16^{th} and 13^{th} position respectively. The highest component values are in Finland (1.8) and Sweden (1.7), the lowest (negative) values in Romania (-2.1) and Bulgaria (-1.9).

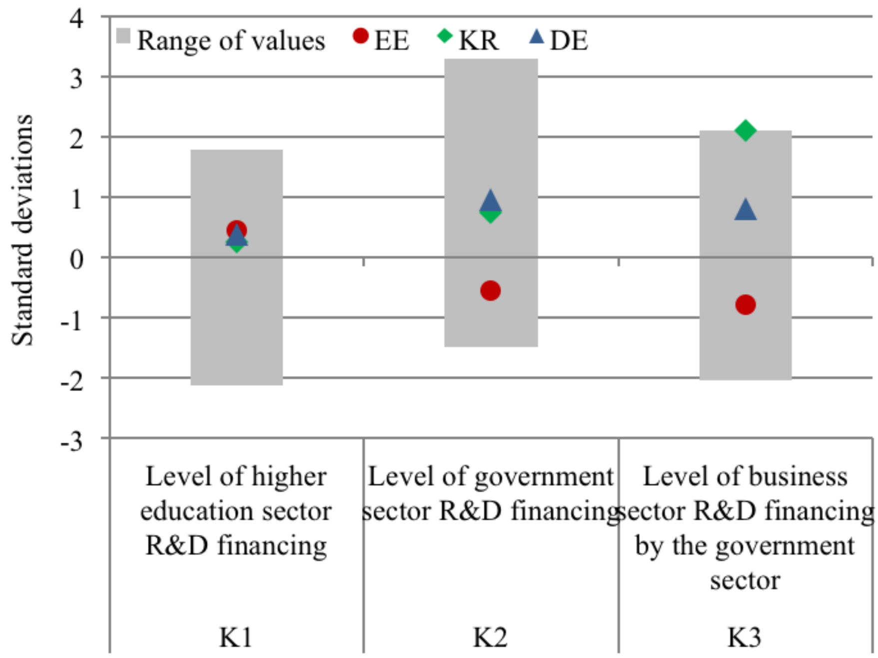

Figure 2.2. Estonian, South Korean and German position among analysed countries using the four components describing public sector R&D policy.

In the case of component K2 (the level of government sector R&D financing), Estonia is 0.56 standard errors lower than the average of analysed countries and is in 24th position. This means that the government sector with its research and scientific personnel does not create remarkable support potential for the business sector and neither is a supportive cooperation partner. In order to find out whether setting such objective would be reasonable at all, it is necessary to study the impact of government sector R&D activities on the business sector. The comparison with other countries offers a few standpoints in this respect. The component scores for South Korea (0.74) and Germany (0.95) are higher than the average level and countries are located in 6th and 5th position respectively. The highest values are in Iceland (3.3) and Bulgaria (1.9) and the lowest in Malta (-1.5) and Turkey (-1.3).

According to the component K3 (the level of business sector R&D financing by the government sector), Estonia is situated below the average level (component score -0.79) and is in 28th position out of 35 countries. The financing of business sector R&D by the government sector demands enough competence to create long-term innovation policy strategies at government level, but also the capability to set and solve very specific development tasks to eliminate market and system failures. Profound research is needed to find out the presence of such competence and capabilities in

Estonia. Thus, the modesty of Estonia in this R&D field can be considered natural. South Korea has a very high component score value (2.10) and is ranked first. Thus, in South Korea the government sector supports business sector R&D to a high level. Germany is situated higher than the average level (component score 0.80) and holds the seventh position. The highest component scores besides South Korea are in Romania (1.8) and France (1.4). The lowest levels are in Lithuania (-2.0) and Greece (-1.6).

As the component analysis includes data from six years, it is also possible to view the dynamics of the component scores. In table 2.5 the dynamics of Estonian, South Korean and German component scores for each year have been given.

Table 2.5. Component scores describing Estonian, South Korean and German public sector R&D policy in 2000, 2002, 2004, 2006, 2008 and 2010

		Estonia	**South Korea**	**Germany**
K1: Level of higher education sector R&D financing	2010	0.68	0.48	0.33
	2008	0.68	0.43	0.30
	2006	0.52	0.22	0.25
	2004	0.43	0.17	0.35
	2002	0.23	0.13	0.52
	2000	0.13	0.15	0.56
K2: Level of government sector R&D financing	2010	-0.55	1.38	1.21
	2008	-0.55	1.06	1.14
	2006	-0.69	0.73	0.91
	2004	-0.53	0.59	0.90
	2002	-0.59	0.41	0.78
	2000	-0.43	0.28	0.74
K3: Level of business sector R&D financing by the government sector	2010	0.21	2.55	0.46
	2008	-0.53	2.09	0.55
	2006	-0.63	1.93	0.60
	2004	-1.35	1.84	0.98
	2002	-0.98	2.16	1.03
	2000	-1.46	2.02	1.19

Table 2.5 shows that for two components (K1 and K3) Estonian component scores have grown over time and the position in comparison to the average level of analysed countries has risen. For component K3 (the level of business sector R&D financing by the government sector), the Estonian position in 2010 was higher than the countries' average, compared to the lower than average component score in 2000. According to component K2 (the level of government sector R&D financing),

the Estonian position has decreased and moved slightly away from the average of counties.

The South Korean position has improved for all components in 2010 compared to 2000 and the values of component scores have always been over the average level (i.e. positive). Thus, South Korea has a higher than the average position in respect of R&D policy implementation.

In addition, German component scores have been always positive for all three components. However, the position of Germany according to components K1 (the level of higher education sector R&D financing) and K3 (the level of business sector R&D financing by the government sector) has decreased during the analysed period.

Finally, a cluster analysis is performed on the three components describing public sector R&D policy. Single linkage hierarchical clustering method is used to group the countries. The dendrogram (figure 2.3) indicates that the most similar country to Estonia is Portugal. Figure 2.3 also shows that Germany is the most similar to its neighbouring country France. South Korea does not have any specific countries that are highly similar to it; however, Germany is slightly more similar to South Korea than Estonia. Compared to the other countries in the scope, the public sector R&D policy is the most different in Iceland, Bulgaria and Romania.

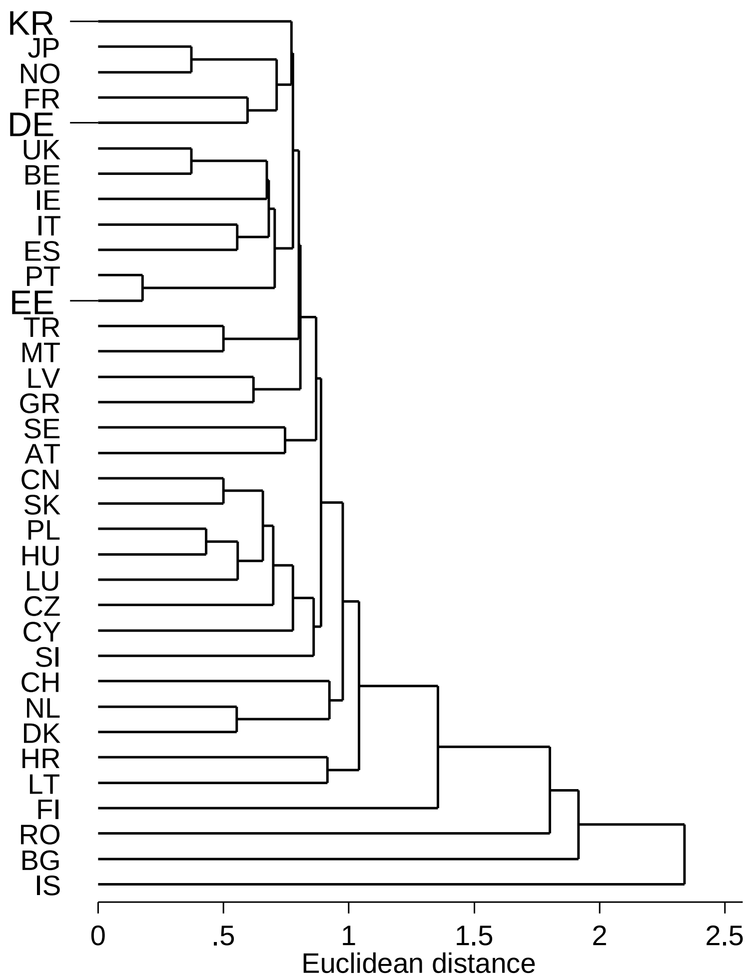

Figure 2.3. Dendrogram grouping countries using components K1, K2 and K3.

Summary

Designing the national R&D policy is a difficult task for the public sector from the aspects of making a choice among the variety of instruments, as well as the nature of the impact that different instruments create. The current study systematised available theoretical approaches for government intervention through R&D policy and gave an assessment to the international position of Estonian, South Korean and German R&D policy implementation based on the empirical analysis of EU member states, countries closely associated with the EU and three Asian countries.

The main reason for public sector R&D policy implementation is to eliminate the market and system failures restraining R&D progress. Market failures are mostly derived from the aspect that in terms of rivalry, innovation and R&D outcomes have a mainly

public good nature and it is often impractical to exclude others from the usage of R&D results. Also, the positive externality of R&D must be taken into account, because the private demand is inevitably lower than the social rational level and with R&D policy measures the demand must be brought to the social utility level. In addition, information constraints do not enable firms to risk long-term R&D investments and the public sector must fulfil this investment gap.

Sometimes, due to a system failure cooperation between different parties of a national innovation system does not function smoothly or some institutions and/or organisations do not fulfil their tasks efficiently. The creation of formal institutions and cooperation organisations that promote R&D development in the country is the responsibility of the public sector. Innovation policy determines the tasks of the R&D policy in promoting innovation in a country and reciprocal connections with the supportive components of the innovation policy (i.e. education policy, cooperation development policy and business environment policy).

Still, intervention by the public sector needs careful analytical justification, because incompetent public sector intervention can distort market processes and create ineligible R&D policy.

Empirical analysis showed that according to most of the indicators that describe public sector R&D activities and the level of government sector support for business sector R&D activities, Estonia and South Korea are below the average level and Germany above the average level among the countries analysed. Component analysis brought out three dimensions of public sector R&D policy:

- K1 – the level of higher education sector R&D financing;
- K2 – the level of government sector R&D financing;
- K3 – the level of business sector R&D financing by the government sector.

Only in the case of K1 (the level of higher education sector R&D financing) is the Estonian average level of six years (2000, 2002, 2004, 2006, 2008, 2010) higher than the average of the analysed countries, whereas according to other R&D policy components Estonia is below the average level. This is a somewhat expected result, as in the case of a small open country external sources are considered important for obtaining innovative knowledge.

South Korea and Germany have a higher than average level of performance in all three components. Thus, South Korea and Germany have a higher than average position in the respect of R&D policy implementation.

Although the position of Estonia according to most components describing government sector R&D policy is relatively modest, an important progress has occurred during the ten-year period (2000-2010). For two components (K1 and K3), the Estonian position in 2010 was relatively higher than in 2000. Also, in South Korea an important progress has occurred during the ten-year period; component scores for all three components have increased. However, the position of Germany has decreased during the ten years: the level of higher education sector R&D financing and the level of business sector R&D financing by the government sector has decreased in 2010 compared to 2000.

We have to take into account quantitative measures of level and changes in R&D policy financing though the government sector brings out only the general features of qualitative nature of this policy in different countries (synthetic components characterise general dimensions of government activities R&D financing). Component scores and their changes do not give the possibility to understand the nature of specific policy measures implemented in different countries in this financial framework.

Acknowledgement

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Appendix 1. Component scores describing public sector R&D activities in the analysed countries (the mean for years 2000, 2002, 2004, 2006, 2008, 2010)

	K1	K2	K3
BE	0.40	-0.69	0.32
BG	-1.88	1.91	-0.95
CZ	-0.73	0.38	1.26
DK	1.28	-0.46	-0.29
DE	0.39	0.95	0.80
EE	0.44	-0.56	-0.79
IE	0.01	-0.94	-0.17
GR	-0.23	-0.63	-1.57
ES	-0.03	-0.08	0.55
FR	0.47	0.74	1.35
IT	0.01	-0.22	0.01
CY	-1.30	-0.61	-0.52
LV	-0.64	-0.70	-1.12
LT	0.14	0.23	-2.03
LU	-1.17	0.51	0.15
HU	-0.77	0.42	-0.23
MT	-0.67	-1.48	-0.93
NL	1.25	-0.02	-0.63
AT	0.95	-1.03	1.11
PL	-1.03	0.08	-0.30
PT	0.32	-0.55	-0.67
RO	-2.12	-0.88	1.82
SI	-0.61	1.11	0.40
SK	-1.24	-0.18	0.42
FI	1.78	1.10	-0.10
SE	1.66	-0.84	1.23
UK	0.66	-0.48	0.50
IS	1.21	3.29	-0.67
NO	0.65	0.32	0.11
CH	1.59	-1.31	-0.11
HR	-0.05	0.47	-1.17
TR	-0.20	-1.32	-0.84
CN	-1.15	0.20	0.72
JP	0.36	0.51	0.24
KR	0.26	0.74	2.10

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