**Slavoj Czesaný**

# CZECH POSITION IN INTERNATIONAL COMPARISON OF R&D SECTOR PERFORMANCE

***Abstract:*** *The aim of this analysis is to identify position of the Czech Republic in international comparison of resources and effects of research, development and innovation. Methodology of the analysis is based on five analytical blocks of indicators covering financial resources, human capital, quality of environment supporting R&D&I advancement, R&D&I outputs and, macroeconomic impacts. The country position in international comparison is identified not only based on individual indicators but also on a composite indicator for each analytical block. In most of scientific and technology development indicators, the Czech Republic is lagging behind the advanced EU countries. The greatest weaknesses of the Czech Republic in comparison with European innovation leaders (Sweden, Germany, Denmark, and Finland) occur in the field of availability of risk capital, cooperation between universities and business sector, patent intensity and, the number of scientific publications per million inhabitants. Current debt and economic crisis hinders progress in Czech research and innovation sector and slows down the processes of real convergence.*

***Keywords****: research sector, financial expenditure, human capital, economic environment, research performance, patent intensity, international comparison, innovation leaders*

**JEL:** O 32, O 38, P 17

## Introduction

The aim of this article is to contribute to the analysis of international comparison of sources and performance of research, development and innovation. From the methodological point of view, the analysis is built on five groups of indicators covering financial resources, human capital, quality of environment supporting R&D&I advancement, R&D&I outputs, and macroeconomic impacts. Altogether, the indicators serve to render a picture of effectiveness of the R&D&I process. To increase the explanatory power, composite (aggregated) indices are constructed for each separate group of indicators.

The analysis fies identi current strengths and weaknesses of the Czech economy and the R&D&I environment, looks also on risks and opportunities in Czech economic outlook and identifies the Czech position in international comparison. For the benchmarking purpose, average values of OECD countries and EU countries were used. The analysis of international comparison is dominated by the following questions: What differences are arising in the characteristics of financial and labour resources? What form do specific trends in countries' research and innovation performance have? In the framework of international comparison, are there prevailing strenghts or weaknesses of the R&D&I advancement in the Czech Republic? What are the opportunities and risks for the future development of science, research and innovation?

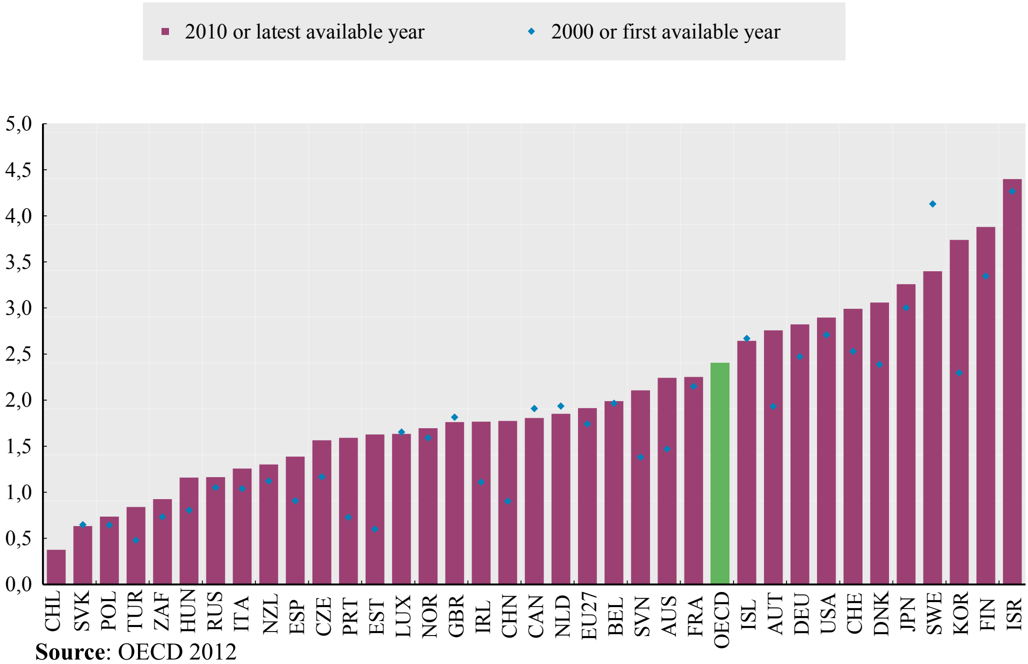
## 1 Financial Resources

The standard indicators for overview and analysis of research funding include the total volume and its sub-components distinguishing public and private resources, or resources for fundamental, experimental and applied research, or even branch resources or resources for individual projects. A characteristic feature of the development of funding of research and development (R & D) is a lagging position of the CzR in international comparison. Total gross expenditure on research and development in the European Union (on average) reached in the first decade of this century the level of 2% in relation to GDP. The Czech Republic has reached the level of about a quarter lower (1.55%). Well above the average is placed Sweden (4.3% of GDP) and Finland (3.4%). In the Czech Republic, total expenditures on research and development have been slightly increasing, even in the years of crisis, and reached the amount of 1.8% of GDP in 2011, but the share of use in the business sector remains almost unchanged.

Among OECD Countries, the United States is the main performer, with 42% of the total OECD GERD in 2009, followed by Japan (15%) and Germany (9%). Since 1999, real R&D outside the OECD area, China‘s average annual real growth in R&D spending has been close to 20%, making it the world's second largest to the R&D performer and ahead of Japan since 2009. In 2009, R&D amounted to 2.4% of GDP for the OECD as a whole. Denmark, Finland, Israel, Japan, Korea, and Sweden were the only OECD countries whose R & D-to-GDP ratio exceeded 3%. Over the last decade, R&D intensity in the EU grew (from 1.74% to 1.91%), in Japan (from 3.00% to 3.26%) and in the United States (from 2.71% to 2.90%). In the same period (2000-10), R&D intensity in China almost doubled, increasing from 0.90% to 1.77%. (Chart 1).

Chart 1

**Gross domestic Expenditure on R & D ( % of GDP)**



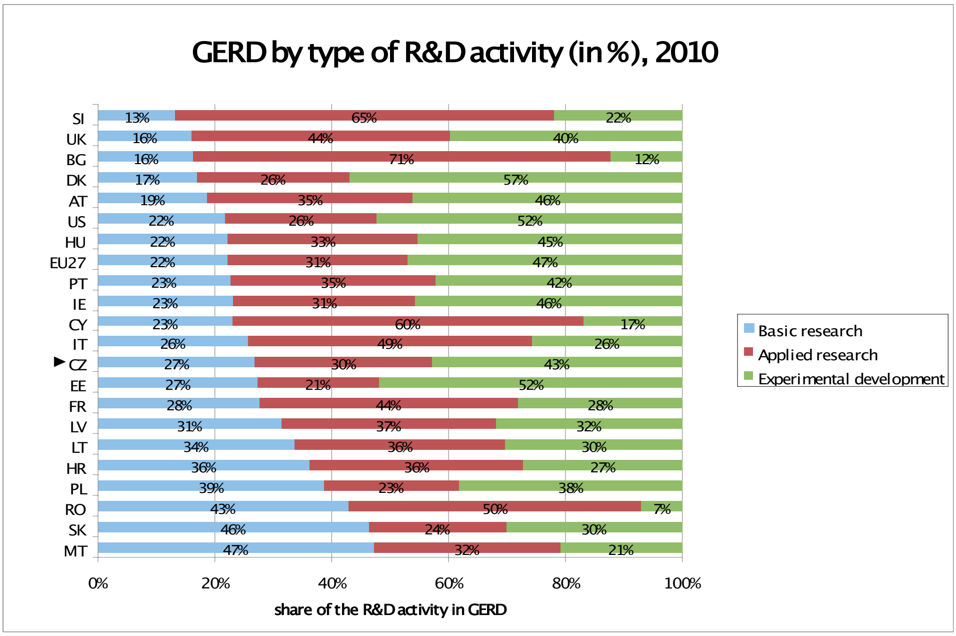

**Source**: OECD 2012

International comparison of the structure of spending on research and development shows a clear diversion of the Czech Republic from the European average. The Czech Republic has a high degree of government involvement – 41% compared to the EU average of 13%. Another area in which the Czech Republic clearly deviates from the average is a relatively low share of R&D carried out in the higher education sector, which is in the Czech Republic around 17%, while the average of EU-15 and EU-27 is about 22%. This phenomenon can be explained as the remnant of the former regime, i.e. from the time when the research was excluded from the traditional scope of universities and was concentrated separately under the Academy of Sciences. The higher education sector now regains its function in R&D back, but very slowly, which is a rather a typical phenomenon in comparison with the other countries of Central and Eastern Europe – in other countries, the role of universities in R&D has considerably strengthened over the last decade (Chart 2).

The share accruing to finance research and development base in the Czech Republic from foreign sources, is the lowest of all Europe, equalling only about 4%, and is roughly half that of the average of EU-15 and EU-27 as well. Foreign enterprises and multinational corporations that invest in the Czech Republic, apparently still lack confidence in the ability of Czech workers to perform more sophisticated work. The labour force in the Czech Republic is relatively inexpensive, efficient, and equipped with quality upper secondary education, therefore, investors invest rather more in factories, assembly plants, or in communication centres. Highly professional activities, including research and development, of course, are preferably being left in the hands of their own research units in their home countries.

Chart 2

**Share of spending on fundamental and applied research and experimental development (2010, in %)**




**Source**: Eurostat – Database: Science and Technology indicators 2013, own calculations

The Czech Republic also shows a significant disparity in the share of fundamental and applied research to the detriment of the applied research, where it lacks extensive potential for innovation. Progress in fundamental research is expected to be made rather in large economies. Comparison of the structure of expenditure on research and development in 2006 and 2000 shows that all post-communist countries have been gradually changing the structure in favour of applied research and experimental development, and the share of the fundamental research has been decreasing. In the Czech Republic, year 2006, the share of fundamental research accounted for almost 30%, which is well above the EU-27 average (23%), USA (18.5%) or Japan (12.6%).

Chart 2 shows that while the proportion of experimental development (46%) is relatively high, applied research remains considerably undersized. A good example of a successful restructuring of the R&D base is Slovenia, which in the last seven years redirected to applied research as much as 20% of the financial resources. A supporting argument for this action was that extensive fundamental research is too expensive for a small open economy.

Low involvement of universities in applied research is rather a global phenomenon, but in the case of the Czech Republic, the latest trend has been especially unfavourable. The share of expenditure on applied research in the higher education sector has been even declining[1] since 1990's: in 1995 the share of applied research ranged around 40%, in 2006 it accounted for only 27% (10). Principal cause of this undesirable development is a continuously poor cooperation between universities and the business sector.

## 2 Human Capital

In the OECD area, around 4.2 million persons were employed as researchers in 2007. There were about 7.6 researchers per thousand of employed people, compared with 5.9 per thousand employed in 1995. This indicator has steadily increased over the last two decades.

The Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) top the table for the numbers of researchers per thousand persons employed, with Finland the highest in the group, and the OECD, recording 17.0 researchers per thousand persons employed in 2010. Among the remaining OECD countries, rates are highest in Korea (11.1), Japan (10.4), and New Zealand (12.4 in 2009), (Chart 3).

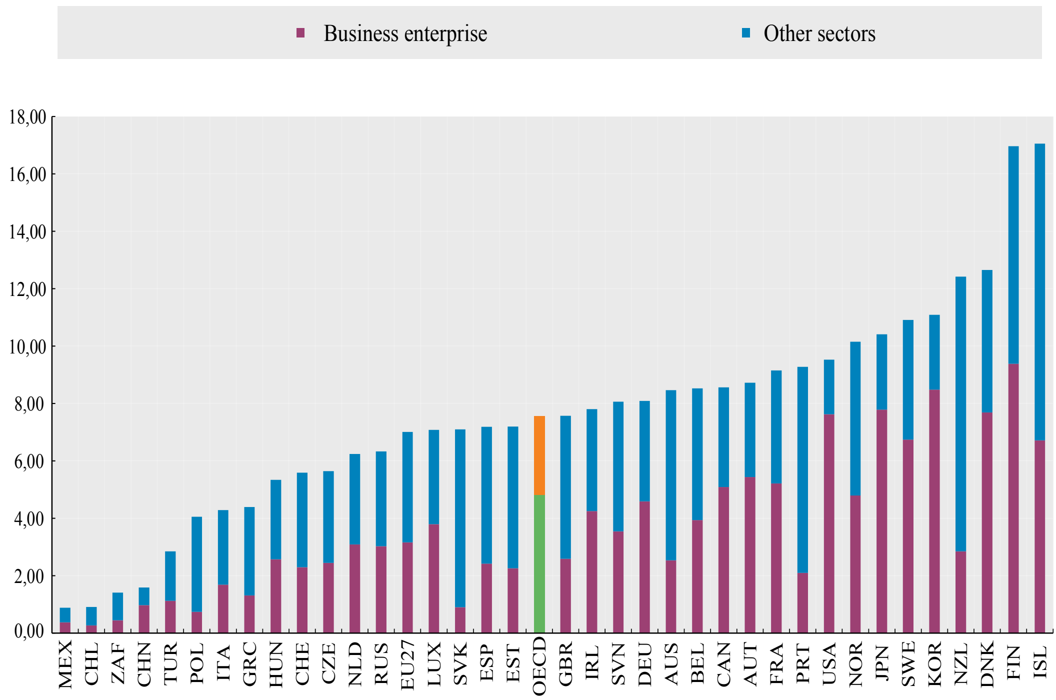
[1] The falling share, however, is not the result of decreasing amounts expended. Expenditure on applied research are growing, but considerably more slowly than how spending on basic research is increasing.

Chart 3

**Share of researchers in individual sectors**

**Researchers**

*Per thousand employed, full-time equivalent*



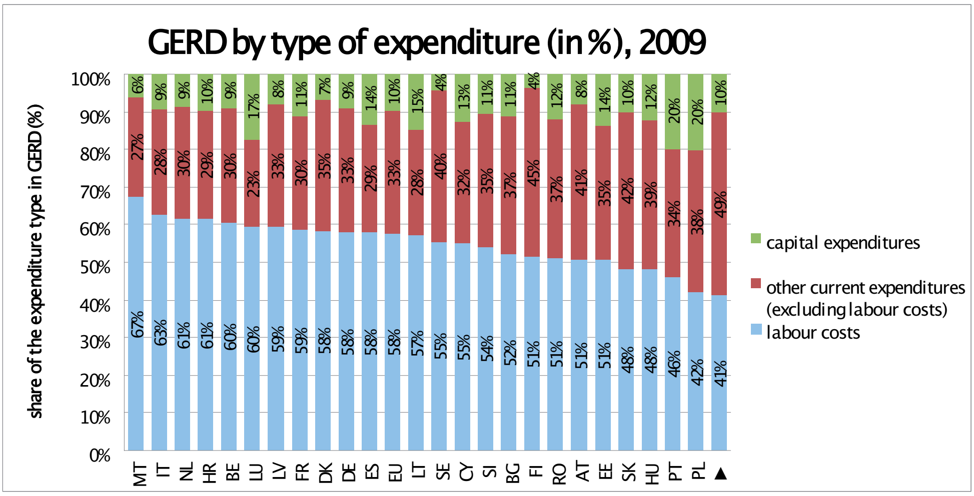

**Source**: OECD

The international comparison also shows that the Czech Republic has the lowest wage share of total costs in Europe. In 2006, the salaries of researchers and other R&D personnel equalled only 34.5% of the total cost, while the EU-27 average is 53%. Low wages of scientific researchers are a great threat to quality Czech R&D, because they act as a de-motivating factor for entering or staying of quality researchers in this sphere and can cause an outflow of workers to financially more attractive job spheres or abroad (See Chart 4).

In euro terms, net salaries of researchers in the Czech Republic are achieving about 30% of the average net wage in the countries of EU-15. After conversion by purchasing power parity position improves, but still does not exceed more than 54% of the EU-15.

Chart 4

**Proportion of each type of expenditure in total expenditure on R & D (2009, in %)**




**Source**: Eurostat – Database: Science and Technology indicators 2013, own calculations

## 3 Innovation Performance

Innovation performance in the EU has improved year on year in spite of the continuing economic crisis, but the innovation divide between Member States is widening. While the most innovative countries have further improved their performance, others have shown a lack of progress. The overall ranking within the EU remains relatively stable, with Sweden at the top, followed by Germany, Denmark and Finland. Estonia, Lithuania and Latvia are the countries that have most improved since last year. Drivers of innovation growth in the EU include SMEs and the commercialisation of innovations, together with excellent research systems. However the fall in business and venture capital investment over the years 2008-2012 has negatively influenced innovation performance.

To assess innovation performance and range of use of innovations, the following indicators have been used: summary innovation index, triadic patent families and overview about position of the Czech Republic to the EU-15.

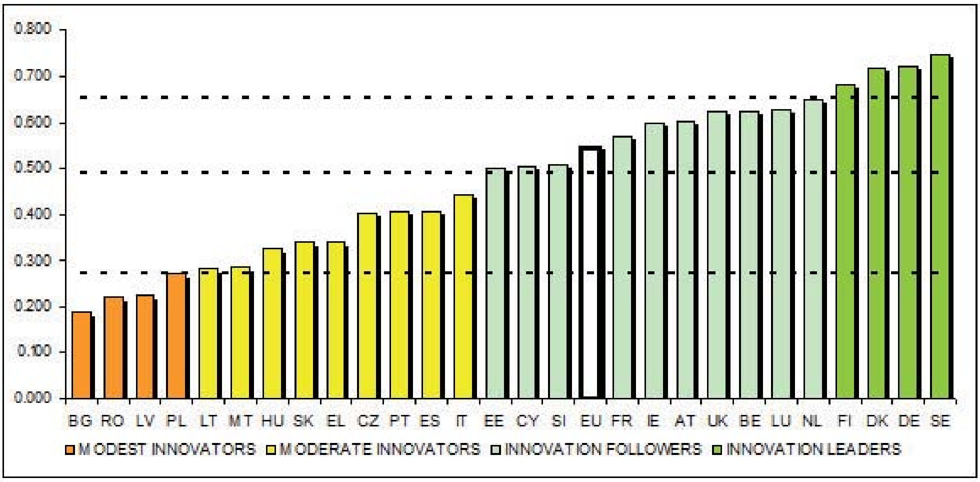
Based on the Summary Innovation Index, the Member States fall into the following four country groups (Chart 5):

- *Innovation leaders:* Sweden, Germany, Denmark and Finland, all show a performance well above that of the EU average.
- *Innovation followers*: Netherlands, Luxembourg, Belgium, the UK, Austria, Ireland, France, Slovenia, Cyprus, and Estonia all show a performance close to that of the EU average.
- *Moderate innovators:* The performance of Italy, Spain, Portugal, Czech Republic, Greece, Slovakia, Hungary, Malta, and Lithuania is below that of the EU average.

- *Modest innovators:* The performance of Poland, Latvia, Romania, and Bulgaria is well below that of the EU average.

Chart 5

**EU Member States' innovation performance**

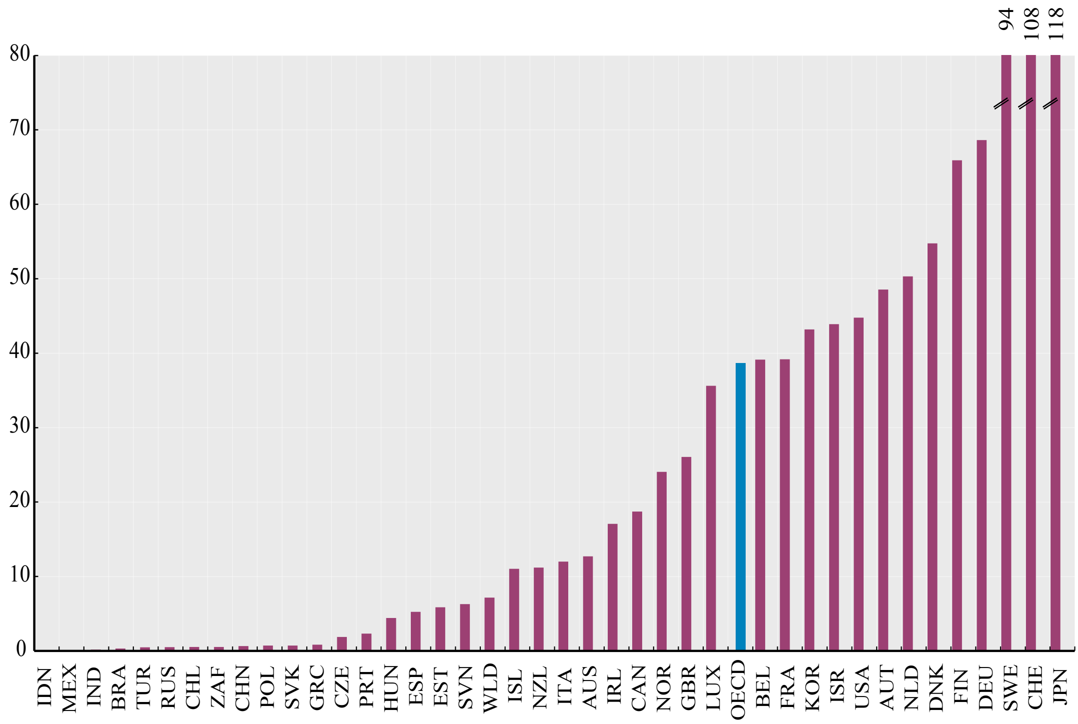



**Source**: Innovation Union Scoreboard 2013, Eurostat
Note: Average performance is measured using a composite indicator building on data for 24 indicators going from a lowest possible performance of 0 to a maximum possible performance of 1. Average performance reflects performance in 2010/2011 due to a lag in data availability.

About 49 000 **triadic patent families** were filed in 2010, compared to over 45,000 registered in 2000. The United States accounts for 28.1% of patent families, a lower share compared to the one recorded in 2000 (30.5%). The share of triadic patent families originating from Europe also tended to decrease, losing almost 1 percentage points between 2000 and 2010 (to 28.6% in 2010). The origin of patent families shifted towards Asian countries. The most spectacular growth was observed by Korea, whose share of all triadic patent families increased from 1.6% in 2000 to 4.4% in 2010. Strong rises are also observed for China and India, with an average growth in the number of triadic patents of more than 28% and 15% a year respectively between 2000 and 2010. Sweden and Germany were the four most inventive countries in 2010, with the highest values recorded in Japan (118) and Switzerland (109). Ratios for Austria, Denmark, Finland, Israel, Korea, the Netherlands and the United States are also above the OECD average (39). Conversely, China has less than 0.7 patent families per million of population (Chart 6).

Chart 6

**Triadic patent families**




**Source**: OECD, 2010

The Czech Republic is lagging behind advanced EU countries in most indicators of the technological development, however, the rate of the lagging varies. The overview of the position of the Czech Republic in international comparison shows not only the position of the Czech Republic within each individual indicator, but also in composite indicators for each analytical block, which is always designed as a simple average of the partial indicators /1/ Individual analytical blocks represent parts of chain from resources devoted to R&D&I activities (financial and human capital), quality of environment supporting R&D&I advancement, to R&D&I outputs and macroeconomic impacts. Based on the clarification of indicators, which are listed in Table 1, it is possible to identify which areas of the chain are among the weakest and which on the other side are closer to the level of developed countries (Table 1).

Table 1

**Position of the Czech Republic to the EU-15 ( %)**

| | | | |
|---|---|---|---|
| I. Indicators of expenditures on R&D&I | 72,7 | IV. Output indicators | 56,6 |
| expenditures on R&D&I as a share of GDP | 80,6 | Patent intensity (EPO/mil. Inhabitants) | 4,9 |
| Share of business expenditure on R&D&I | 98,5 | Number of scientific publications/mil. inhabitants | 52,0 |
| Share of expenditure on the applied research | 65,3 | Relative citation impact factor of publications | 63,4 |
| Wages as a share of R&D&I expenditures | 60,5 | Implementation of innovations | 106,2 |
| Ratio of the wage of the R&D workers to the average wage | 59,0 | | |
| II. Indicators of human capital input to R&D&I | 87,5 | V. Indicators of macroeconomic effects | 50,2 |
| R&D workers as a share of total employees | 84,5 | Labor productivity | 67,9 |
| Share of university graduates in given age group | 78,4 | Energy intensity (inverse value) | 22,8 |
| Share of PhD. graduates in given age group | 70,9 | Material intensity (inverse value] | 31,2 |
| | | Export/import of high-tech products ratio | 89,8 |
| III. Indicators of environment quality | 33,7 | Technology payment balance | 39,5 |
| Cooperation of universities and business sector | 11,0 | | |
| Availability of risk capital | 6,0 | | |
| Quality of ICT infrastructure | 71,2 | | |
| Expenditures per one university student | 63,8 | | |

**Source**: Eurostat 2008, 2009,
Note: EU-15 = 100%

## 4 Opportunities and Risks

Identifying weaknesses in research and development processes can to some extent serve to direct R&D activities in the upcoming period. The main opportunities for catching up with R&D level of developed countries include strengthening of cooperation and coordination among all sectors and promotion of supportive quality infrastructure specialized on expert advice and assistance, to private and public research units. The expert support is needed mainly in the areas as: protection of intellectual property rights, preparation of projects and grant applications from domestic and European public funds, or establishing contacts with other agents from R&D base. It is necessary to promote links between research spheres of government and university sites and private application/innovation sector to facilitate the transfer of knowledge into practice, where it can be commercialized. Compared with foreign experience, the small and medium-sized enterprises in the Czech Republic are not sufficiently involved in the research activities [10].

If you are looking for opportunities for further progress in science and research, as an inspiration for the Czech Republic can be experience of those countries that have a very good track record in innovation performance, which are mainly Sweden, Germany and Finland. Inspiring can be especially institutional arrangements in these countries, particularly forms and methods of co-ordination of research activities, which is one of the weaknesses of research in the Czech Republic.

As inspiration for the process, how to shape a national strategy for research and innovation policy can serve the knowledge of the formation of research and innovation strategies in Sweden, which has been for many years occupying the leading position in charts concerning success of innovative processes. In the creation of Swedish research and innovation policies, industry groups, providers of risk capital, research communities, commercial agencies, EU institutions and the media are involved. Sweden is a country with a decentralized system of government in research and development.

Research is coordinated by two main lines. The main share of responsibility for research and development is in the hands of the Ministry of Industry and Trade. Within its purview is also mainly the coordination of activities of the research institutes. Ministry of Education and Science is responsible for research carried out within the learning process, the Swedish National Committee for Industrial and Technical Development serves as a government advisory body on issues of industrial research.

The main axes of development of research activities in Sweden are, by funds provided, fields in electrical engineering and optics, vehicles, and some other fields of engineering and chemistry. The second axis, with some smaller amounts of funding sources, includes the paper industry, metallurgy, energy and construction. The priorities of the national innovation strategy include research in engineering, sustainable development and improving knowledge transfer between universities, industry and commercial companies.

The structure of the allocation of public resources is divided into two branches. The first branch is generated by social needs (social demand) and the second branch is represented by research demanded by the business sector. The share of financial resources defined by social demand accounts for about 50%, and is covered by in the agencies for innovation systems, energy, public research funds, and national defence. Selection of national priorities is influenced by several factors, i.e. quality of ideas, collaboration possibilities, team composition, international participation, competences, availability of research equipment, and geographical conditions. Specialization evolves at the regional level, such as the biotechnology research being developed in Gothenburg and Uppsala, in other regions is then concentrated research on nanotechnology and robotics [9].

In Germany, we are seeing as a centralized system with a number of special features resulting from a federal state constitution. Creation of state R&D policy and a substantial part of its implementation is in the hands of the Federal Ministry of Education and Research. The main body for inter-ministerial coordination is the Scientific Council appointed by the Federal President based on a joint proposal of major research institutions, regional and federal governments. Members of the Council are leading personalities from the R&D sphere. The task of the Scientific Council is preparation of recommendations of content and structural development of higher education, science and research in Germany and elaboration of expert opinions based on requirements of the federal states.

Finland, like other Nordic countries has a decentralized system of government in research and development. Pivotal role in the allocation of financial resources is played by the Ministry of Industry and Trade and its Centre for Technological Development, the Ministry of Education, Science and Culture, which manages councils of universities and research institutes. Coordinating body is the Finnish Council for Science and Technology Policy, headed by the Prime Minister. The uniqueness of this body is that the dominating priority in terms of technology policy is clear already from its name. The members include the Minister of Education, Minister of Industry and Trade and two ministers, the president of the Academy of Finland, representatives of the Council for Higher Education, the Council for Industry and selected experts [12].

## Conclusion

Analysis of the effects of the innovation process in the Czech Republic showed superiority weaknesses concerning both labour and financial resources, and research performance. The lack of evaluation of the effectiveness of research and development has negative consequences – there are no criteria and guidelines for effective targeting and allocation of funds in upcoming period. Substandard wages and thus little motivation for researchers in the applied research sphere hinders the performance of the R&D sphere and is one of the triggers for the departure of scientists abroad. Low international mobility of researchers slows progress in research activities. Small citation of scientific publications shows that there are not very good conditions for increased development of fundamental research in a small country.

The low rate of use of venture capital shows that there is a persisting lack of confidence of entrepreneurs regarding the research potential in the country. There is a missing identification of the public demand for major technological projects, which would focus the research on the vulnerabilities of technological development. These are indicated e.g. by the high energy and material consumption, low productivity of labour and capital, especially for small and medium-sized Czech companies. Long-term low quality of the institutional environment is a big risk for slowing the growth of competitiveness in the future.

Foreign experience shows emphasis on system management applied in the innovation sector, motivational wages, predominance of applied research in small open economies and identification of priorities for research and innovation activities. The definition of coordination rules is usually practised at the level of relevant ministries as well as the wider constellation including universities, industry bodies, and commercial companies.

## Literature


[1] CZESANÁ, V. *Investice do vědy výzkumu a inovací: případ České republiky*. (Investment in science, research and innovations: case of the Czech Republic). Praha :VŠE Praha, 2009, 94 s., final thesis.

[2] CZESANÝ, S. – JOHNSON, Z.: *Ekonomický cyklus, hospodářská politika a bohatství zemí.* (Economic cycle, economic policy and wealth of countries). Nakladatelství Oeconomica, VŠE, Praha, 2012, 235 s. ISBN 978-80-245-1863-3.

[3] European Innovation Scoreboard: Comparative analysis of innovation performance, INNO, 2013. Available at: http://www.proinno-europe.eu/metrics

[4] European Innovation Progress Report 2008. Available at: http://www.proinno-europe.eu/admin/uploaded_documents/EIRP2008_Final_merged.pdf

[5] Remuneration of Researchers in Public and Private Sectors: CARSA. 2007. Available at: http://ec.europa.eu/euraxess/pdf/final_report.pdf

[6] Annual Report: European Patent Office, 2010.

[7] GUELLEC, D. – van POTTELSBERGE, B.: *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries.* OECD, Paris, 2001. ISBN 951-38-6601-7.

[8] GRILICHES, Z.: *R&D, Education, and Productivity: A Retrospective*. Harvard University, Cambridge, 2001 144 p. ISBN 97806740003439.

[9] GUSTASSON, L.: *Choosing national research priorities in Sweden*. Conference, Bangkog 2007. ISSN 1403-6304.

[10] KLUSÁČEK, K., – KUČERA, Z., – PAZOUR, M.: *Zelená kniha výzkumu, vývoje a inovací v České republice – Analytická část.* (Green Book of Research Development and Innovations in the Czech Republic – Analytical Part). Technologické centrum AV ČR, Praha, 2008 http://forum.tc.cz/co-je-zelena-kniha/

[11] KLUSÁČEK, K., – KUČERA, Z., – PAZOUR, M.: *Bílá kniha výzkumu, vývoje a inovací v České republice.* (White Book of Research Development and Innovations in the Czech Republic). Praha : Technologické centrum AV ČR, 2008. ISBN 9778-80-86429-99-1

[12] Science, Technology and Industry Outlook: OECD 2008-2012, Paris. Available at: http://www.oecd.org/sti/outlook

[13] SLANÝ, A. ET AL.: *Konkurenceschopnost a stabilita*. (Competitiveness and stability). Brno : Masarykova universita, 2010, 281 s., ISBN 978-80-210-5336-6.

[14] Analýza stavu výzkumu, vývoje a inovací v České republice a jejich srovnání se zahraničím v roce 2008. (Analysis into state-of-the-art of research, development and innovations in the Czech Republic and their comparison with other countries in the year 2008). Úřad vlády ČR, Praha, ISBN 987-80-87041-49-9.

[15] The Global Competitiveness Report: WEF 2012-2013. Available at: http://reports.weforum.org/global-competitiveness-report-2012-2013/#=