# A TYPOLOGY OF THE BALTIC REGION STATES ACCORDING TO EXCELLENCE IN SCIENCE AND TECHNOLOGY

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*Global manufacturing systems function in such a way that countries develop industrial specialisation, which leads to territorial disparities. The countries of the Baltic region are no exception despite their strong economic ties and developed industries. A significant element of any manufacturing system is its scientific and technological subsystem, which is described in this article for ten countries (Germany, Sweden, Denmark, Norway, Finland, Poland, Estonia, Latvia, Lithuania and Russia), based on an analysis of a clustered set of national characteristics: R&D financing and staffing in the scientific and technological subsystem. A total of ten indicators, absolute and relative, are investigated. The study relies on combined grouping, graphical and cluster analysis to build a typology of countries and distinguish their types according to their scientific and technological excellence As a result, a typology of the countries of the Baltic Sea region has been proposed and types of countries with similar characteristics have been identified: the two main types are traditional market economies and post-socialist countries, whose common features are observed in all sets of main characteristics. Several subtypes are described as well. The research draws on 2010—2019 (2020) statistical data from the European Statistical Office (Eurostat), the Organization for Economic Co-operation and Development (OECD) and Russia's Federal State Statistics Service (Rosstat).*

**Keywords:**
scientific and technological development, country-specific assets, manufacturing system, scientific and technological subsystem, gross domestic expenditure on R&D, intramural R&D expenditures, personnel potential

## Introduction

The research and technological component is an integral part of the global production systems (GPS) and its scientific and technological subsystem (STS). This subsystem comprises a complex network of economic, financial, and legal

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connections whose primary goal is to facilitate the exchange of research, development activities, and technological work. To date, there is no well-established and generally recognized system for assessing the scientific and technological development of territories. However, there are common patterns of development in scientific and technological progress across different countries [1]. The selection of these patterns will depend on the authors' interests in various aspects and subtleties of the subject.

Russian authors are mainly focused on the governmental role in scientific and technological development, describing it as a crucial factor [2; 3] or, at the very least, not insignificant [4]. In fact, the state is primarily responsible for promoting scientific and technological progress in Russia, as it is considered to be lagging behind leading countries due to an economy that is heavily reliant on exporting raw materials [1; 2; 5]. A number of papers substantiate the need for collaboration for the sake of scientific and technological development at the level of national industry and science [1], as well as at the level of the CIS member states [6] and the EAEU [7].

Having analyzed the indicators of scientific and technological space, most authors from the former USSR countries pay attention to the volume of investments in science [5; 8] and HR [3; 8], as well as some other indicators, such as a number of patents [8]. Certain studies offer complex integral indicators derived from expert assessment [9].

When discussing the causes behind territorial disparities, it is pertinent to delve into the scholarly contributions of Baburin and Zemtsov, who argue that the level of regional development is heavily dependent on the proximity of regions to the hubs that generate and disseminate innovative knowledge [10]. However, it is noted that in the post-Soviet space such centres have little impact on development [11; 12]. Furthermore, the impact of historical circumstances, commonly known as the 'rut effect' in national research [13; 14], assumes a noteworthy role in shaping regional development outcomes.

The entirety of the Western literature analyzed in this study aims to comprehend the role of businesses in the developmental process and seeks to refine corporate strategies while integrating within the sphere of international business. To date, the main generally accepted vector is neo-institutional economic theory, within which several paradigms have been developed which can be used for the study of regions:

— eclectic paradigm (OLI model);
— knowledge capital model;
— FSA-CSA matrix paradigm.

The eclectic paradigm, which has been developing for more than three decades, considers the ownership of firms (O), the advantages of their location in specific territories (L) and the advantages of internationalization (I) [15]. The study of countries within this paradigm focuses on formal and informal institutions, consumption patterns, market structure, socio-economic, natural conditions, working conditions, and the education systems development [16]. Notably, researchers have employed this paradigm to demonstrate that globalization has failed to enable the participation of less developed countries in the global production sharing (GPS) network, which would have ostensibly facilitated their development [17; 18].

Within the knowledge capital model, researchers analyze knowledge, skills and qualifications of labour resources [19], including management skills as the main development factor. The typology here is based on the cost of the geographical division of functions ('fragmentation cost') [20], concentrated on the level of training [21]. These studies assume that excessive specialization of regions leads to a reduction in the well-being of the population [22], and, consequently, to a drop in the level of development.

Within the FSA-CSA matrix paradigm, the development of GPS is influenced by investments of transnational corporations (TNCs), as well as government initiatives to create favourable conditions and develop infrastructure [16]. The recognition of this dichotomy has engendered two distinct perspectives on the unit of analysis for GPS [23]. On one hand, it encompasses the investigation of country-specific advantages that define their competitiveness. On the other hand, it focuses on firm-specific advantages, such as proprietary competencies (assets, patents, trademarks), among others. Given their interdependence, the specific advantages of countries and firms, also known as the FSA-CSA matrix, can be construed as a composite of specific country characteristics [24]. Analogously, a comparable framework can be employed to scrutinize scientific and technological progress as a component of the production system.

Developed countries and transnational corporations of the world are not able to conduct comprehensive scientific research on their own, which creates certain conditions for ever greater globalization of production systems and, as a result, leads to more intensive participation of the main actors in the global division of labour [25].

The degree of scientific and technical progress of countries is an indicator of the development of industrial relations, and other related governmental and social institutions [2]. Thus, increased investment in science has a positive efe fect on GDP [26], and the economic growth of agglomerations is promoted by knowledge-intensive industries [27].

For over a decade, the evolution of global economic relations has transpired within the framework of globalization and internationalization. The advent of GPS has inevitably resulted in a geographical reorganization, an asymmetric development of territories, and a form of "spatial fixation" [28]. The territorial dynamics of scientific and technological progress is no exception; on the contrary, the intrinsically international character of science amplifies existing trends. In this regard, there is a need to assess the level and trends in the development of the scientific and technical progress of the Russian Federation in comparison with other countries of the Baltic Sea region, to identify promising areas for its innovative development, taking into account international experience. The aim of this study is to classify countries in the Baltic Sea region according to their level of scientific and technological development and to elucidate the specific trends and patterns within this context.

## Research methodology

Our analysis focuses on ten countries of the Baltic Sea region, as they offer a diverse range of study material for our investigation. In addition to the fact that one of the world's leading economies (the Federal Republic of Germany) is located on the territory of the Baltic Sea region, this territory is special for a number of other reasons. Firstly, the region is characterized by a developed industry and a high level of human capital potential, making it one of the most developed international areas [29]. Secondly, five out of the ten countries in the region were previously part of the "people's democracy" or the Soviet Union, and therefore share similarities in their development paths with the Russian Federation. Thirdly, the countries in the region have a long history of economic ties and relations that extend beyond the four freedoms of the European Union. R&D funding and the state of labour resources are the key factors in the analysis of scientific, technological and innovative development of territories [8; 10; 30]. Therefore, the specific advantages of the countries used to compile the typology are divided into two groups: R&D funding and the state of the STS workforce.

R&D funding is considered one of the key components of science, technology, and innovation systems (STS). The measurement of R&D funding is typically done by analyzing the gross domestic expenditure on R&D (GERD). This indicator provides information on the research and development expenditures of commercial enterprises, higher education institutions, government agencies, and private non-profit organizations. GERD is usually expressed as a percentage of the gross domestic product or in absolute values.[1]

The state of the labour force in relation to scientific and technical progress is assessed through the use of the statistical indicator known as the 'total number of researchers' (R&D personnel). This indicator encompasses individuals who are either fully or partially employed in R&D, in full-time equivalent roles, and are engaged in the development of new knowledge, products, processes, methods, and systems, as well as the management of research projects. To provide context for the importance of scientific personnel in the context of a country's scientific and technical progress, it is also necessary to consider the "population size" indicator, which represents the number of people who permanently reside in a given country.[2]

[1] Gross domestic expenditure on R & D (GERD), 2022, *Eurostat*, URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary: Gross_domestic_expenditure_on_R_%26_D_(GERD) (accessed 17.07.2022).

[2] Demography — Population — OECD Data, 2022, *OECD*, URL: https://data.oecd.org/pop/population.htm#indicator-chart (accessed 17.07.2022).

R&D funding, as well as employment of the personnel, engages several sectors, which are to be analyzed:

— Government sector — R&D (GOV), which includes state and non-profit organizations under governmental control;

— business enterprise sector — R&D (BES), which includes organisations and institutions whose main activity is market production of goods and services (except for higher education);

— higher education sector (R&D (HES)), which, in addition to universities, colleges and other higher education organisations, includes research institutes, experimental stations and other organizations operating under the direct control or management of higher education institutions or any other associated with them;

— private non-profit sector (R&D (PNP)) includes private non-profit organisations such as professional, research societies, charitable organizations, charitable foundations, trade unions, etc.;

— foreign (international) sector — (foreign R&D)[3] includes all legal entities and individuals located outside the political borders of the state, excluding vehicles, ships, aerospace equipment, test sites operated by these organizations, as well as all international organizations (with the exception of commercial enterprises [4]).

The data source is the databases of the Federal State Statistics Service of the Russian Federation (Rosstat), the Statistical Service of the European Union (Eurostat) and the Organization for Economic Cooperation and Development (OECD).

The study conducted a comprehensive analysis of a large time series of statistical indicators, employing combined grouping to categorize the selected countries based on two or more criteria. The analysis also identified quantitative dependencies between related indicators using graph-analytical methods and utilized cluster analysis to identify patterns and groupings within the data set.

To form the groups, a set of interval discrete features was identified, which were related to the growth rate of absolute R&D costs, the structure of R&D financing, the growth rate of the absolute number of researchers, and the structure of researchers' employment. The following indicators were selected as variables for conducting graph-analytical and cluster analyses: gross domestic expenditure on R&D (% of GDP) and the number of researchers per 1000 inhabitants. These indicators were considered the most important characteristics of each group that could help to characterize scientific and technological development. The cluster analysis was performed using IBM SPSS Statistics ver.22 software, applying the hierarchical clustering method with squared Euclidean distance and Ward's connection method.

[3] When analyzing the condition of labour resources of scientific and technological progress, this sector is not used.

[4] Science and technology glossary — Statistics Explained, 2022, *Eurostat*, URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Category:Science_and_technology_glossary (accessed 17.04.2022).

## Results

### *R&D Funding*

The Baltic Sea region countries can be differentiated based on their level of R&D funding in absolute terms. In 2020, the leader was Germany, whose total R&D spending amounted to about 105 billion euros, or 63 % of the total R&D spending of all the analyzed countries in the region. Sweden ranks second with about 16.5 billion euros (9.9 %), and third place — Russia with 14.2 billion euros, or 8.3 % (Table 1).

*Table 1*

**R&D Funding, billion euros**

| Country | 2010 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| *Market economy countries* | | | | | | | | |
| Germany | 70.01 | 84.25 | 88.78 | 92.17 | 99.55 | 104.67 | 110.02 | 105.55 |
| Sweden | 11.87 | 13.61 | 14.66 | 15.14 | 16.14 | 15.63 | 16.15 | 16.77 |
| Denmark | 7.09 | 7.74 | 8.34 | 8.76 | 8.61 | 8.97 | 9.1 | 9.46 |
| Norway | 5.34 | 6.45 | 6.73 | 6.82 | 7.42 | 7.58 | 7.8 | 7.25 |
| Finland | 6.97 | 6.51 | 6.07 | 5.93 | 6.17 | 6.44 | 6.72 | 6.93 |
| *Post-socialist countries* | | | | | | | | |
| Russia | 13.00 | 16.63 | 13.44 | 14.45 | 15.46 | 13.89 | 15.66 | 14.04 |
| Poland | 2.61 | 3.86 | 4.32 | 4.11 | 4.83 | 6.02 | 7.05 | 7.3 |
| Estonia | 0.23 | 0.29 | 0.30 | 0.27 | 0.30 | 0.37 | 0.45 | 0.48 |
| Latvia | 0.11 | 0.16 | 0.15 | 0.11 | 0.14 | 0.19 | 0.20 | 0.21 |
| Lithuania | 0.22 | 0.38 | 0.39 | 0.33 | 0.38 | 0.43 | 0.48 | 0.57 |

*Source:* GERD by sector of performance and source of funds, 2022, *Eurostat,* URL: https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDTOT__custom_2252073/default/table?lang=en (accessed 10.05.2022) ; Expenditure on science, 2022*, Science, technologies, innovations,* URL: https://issek.hse.ru/mirror/pubs/share/504081839.pdf (accessed 12.07.2022) ; Russia and the countries of the world, 2021*, Federal State Satistics Service*, URL: https://rosstat.gov.ru/folder/210/document/13241 (accessed 26.06.2022).

Over the past 20 years, gross domestic spending on R&D in Russia has remained virtually unchanged and amounts to about 1 % of GDP. Based on this particular indicator, the Russian Federation falls behind the developed countries in the region by a factor of two. By analyzing the data, it is possible to classify the countries into two distinct groups, as shown in Table 2. On the one hand, these are countries having a traditional market economy, on the other — post-socialist countries (countries of the former USSR and people’s democracy).

*Table 2*

**Gross domestic expenditure on R&D, % of GDP**

| Country | 2010 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| *Market economy countries* | | | | | | | | |
| Sweden | 3.17 | 3.1 | 3.22 | 3.25 | 3.36 | 3.32 | 3.39 | 3.51 |
| Germany | 2.73 | 2.88 | 2.93 | 2.94 | 3.05 | 3.12 | 3.17 | 3.14 |
| Denmark | 2.92 | 2.91 | 3.06 | 3.09 | 3.03 | 3.02 | 2.93 | 3.03 |
| Finland | 3.71 | 3.15 | 2.87 | 2.72 | 2.73 | 2.76 | 2.8 | 2.94 |
| Norway | 1.65 | 1.72 | 1.94 | 2.04 | 2.1 | 2.06 | 2.15 | 2.3 |
| *Post-socialist countries* | | | | | | | | |
| Estonia | 1.57 | 1.42 | 1.46 | 1.23 | 1.28 | 1.41 | 1.63 | 1.79 |
| Poland | 0.72 | 0.94 | 1 | 0.96 | 1.03 | 1.21 | 1.32 | 1.39 |
| Lithuania | 0.78 | 1.03 | 1.04 | 0.84 | 0.9 | 0.94 | 1.0 | 1.17 |
| Russia | 1.05 | 1.07 | 1.1 | 1.1 | 1.11 | 0.98 | 1.04 | 1.1 |
| Latvia | 0.61 | 0.69 | 0.62 | 0.44 | 0.51 | 0.64 | 0.64 | 0.7 |

*Source:* GERD by sector of performance and source of funds, 2022, *Eurostat,* URL: https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDTOT__custom_2252073/default/table?lang=en (accessed 10.05.2022) ; Expenditure on science, 2022*, Science, technologies, innovations*, URL: https://issek.hse.ru/mirror/pubs/share/504081839.pdf accessed 12.07.2022) ; Russia and the countries of the world, 2021*, Federal State Statistics Service*, URL: https://rosstat.gov.ru/folder/210/document/13241 (accessed 26.06.2022).

The countries in the first group receive substantial funds from the commercial sector of their economies, with more than 50 % of funding coming from the Business Enterprise Sector — Research and Development (BES-R&D), except for Norway. This allocation of funds reflects the modern economic model, which emphasizes the importance of research to the national economy and shows the private sector's interest in long-term development. Moreover, it highlights the readiness of businesses to finance high-risk long-term development programs. It also shows the stability of the financing structure. The case is different for Finland, where the rate of R&D funding by the commercial sector of the economy (Business enterprise sector — R&D (BES)) was the highest among the countries of the Baltic region at the beginning of the reviewed period, but from 2010 to 2019 it decreased from 66.1 to 54.3 %. Norway is also characterized by a fairly high rate of R&D funding by the government sector (R&D (GOV).

The Nordic countries (Denmark, Sweden, Norway and Finland) when compared to other ones are characterized by a large (more than 1 %) and increasing rate of R&D funding by the private non-profit sector (R&D (PNP)). In other countries with a high level of R&D funding, this figure is negligible.

Post-socialist countries have a fairly high indicator of R&D funding by the government sector (R&D (GOV)) — above 30 %. Unlike other countries in its group, Russia demonstrates stability in the structure of funding for scientific and technical progress with a high predominance of the public sector. Poland underwent a remarkable transformation during the analyzed period. While its public funding for research and development (R&D) remains comparatively high when compared to traditional market economies, it decreased from 60.9 % in 2010 to 38.8 % in 2019. As for the indicator of R&D funding from abroad (foreign sector — R&D), it is significant for the Baltic countries and Finland. In Russia, this indicator is low and tends to decrease even more: from 3.5 % in 2010 to 2.5 % in 2019. The Baltic countries (Estonia, Latvia and Lithuania) are characterized by the absence of a stable structure of gross domestic expenditure on R&D (GERD). The reasons are the low level of absolute financing costs compared to neighbours. In such a situation, the implementation of any science-intensive project has a significant impact on the structure of gross domestic expenditure on R&D (GERD) [31].[5]

An analysis of R&D financing in the higher education sector (R&D (HES)) did not reveal any significant patterns.

In terms of the growth rate of absolute R&D expenditure since 2010, Russia has ranked penultimate among the Baltic Sea countries — in 2020 it amounted to only 8 %. Finland experienced a negative growth rate of its Gross Domestic Expenditure on Research and Development (GERD) in 2020, which fell by 0.5 % compared to 2010. However, since 2016, there has been a gradual increase in the indicator. In contrast, Poland leads the region with a significant growth rate of 179.7 %, followed by Lithuania at 160.4 %, Estonia at 106.6 %, Latvia at 91.6 %, Germany at 51.2 %, Sweden at 41 %, Norway at 35.5 %, and Denmark at 33.3 % (see Table 1).

When analyzing the countries of the Baltic region in terms of their level of research and development (R&D) funding, significant diversity can be observed. As of 2020, the total population of the ten countries analyzed stood at approximately 300 million people, with this number remaining relatively stable over the past ten years and experiencing only a slight increase.

## Labour resources of STP

In 2020, the population of Russia accounted for 146.5 million people or 48.7 %, which makes it an absolute leader, while Germany with 83.2 million, or 28 % ranked second, and Poland was third with 38 million, or 12.6 %.[6, 7]

[5] GERD by sector of performance and source of funds, 2022, *Eurostat*, URL: https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDTOT__custom_2252073/default/table?lang=en (accessed 13.03.2022).

[6] Population, 2022, *OECD Data,* URL: https://data.oecd.org/pop/population.htm#indicator-chart (accessed 08.07.2022).

[7] Russia and the countries of the world, 2020*, Federal State Statistics Service,* URL: https://rosstat.gov.ru/folder/210/document/13241 (accessed 04.04.2022).

A similar situation is observed when considering the total number of researchers, but in 2019 Russia was second in the ranking — 400,663 people employed in R&D, Germany was the first — 450,697 people, and Poland was third — 120,780 people.[8]

For an objective comparison, we will consider the total number of researchers per 1,000 inhabitants. The analysis of this indicator reveals that the countries can be divided into two groups: countries with a market economy and post-socialist countries (Table 3).

*Table 3*

**Number of researchers per 1,000 residents**

| Country | 2010 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| *Market economy countries* | | | | | | | |
| Sweden | 5.3 | 6.9 | 6.8 | 7.1 | 7.3 | 7.4 | 7.7 |
| Denmark | 6.8 | 7.3 | 7.5 | 7.8 | 7.6 | 7.6 | 7.7 |
| Finland | 7.7 | 7 | 6.8 | 6.5 | 6.7 | 6.9 | 7.2 |
| Norway | 5.4 | 5.7 | 5.9 | 6.1 | 6.4 | 6.5 | 6.7 |
| Germany | 4 | 4.3 | 4.7 | 4.9 | 5.1 | 5.2 | 5.4 |
| *Post-socialist countries* | | | | | | | |
| Estonia | 3.1 | 3.3 | 3.2 | 3.3 | 3.5 | 3.8 | 3.8 |
| Lithuania | 2.8 | 3.1 | 2.8 | 3.0 | 3.1 | 3.2 | 3.4 |
| Poland | 1.7 | 2.0 | 2.1 | 2.3 | 3.0 | 3.1 | 3.2 |
| Russia | 3.1 | 3.1 | 3.1 | 3.0 | 2.8 | 2.8 | 2.7 |
| Latvia | 1.9 | 1.9 | 1.8 | 1.6 | 1.8 | 1.8 | 1.9 |

*Source:* R&D personnel by sector of performance, professional position and sex, 2022, *Eurostat,* URL: https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSOCC/default/table?lang=en (accessed 07.02.2022).

The indicator of the human resources structure of those employed in the scientific and technical field can demonstrate a number of features. Thus, for Russia, it is traditional to have a larger number of researchers (>30 %) employed in enterprises and institutions of the government sector (R&D (GOV)) than in other countries. All countries are characterized by a decrease in the employment of researchers in this sector, especially Poland (from 21 % in 2010 to 1.8 % in 2019), mainly due to an increase in the indicators of the business enterprise sector (R&D (BES)).

Science funding by the Higher Education Sector (R&D (HES)) is insignificant, but higher education institutions have traditionally employed a large number of researchers. This indicator divides countries into two groups: the ones

[8] Total number of researchers by sectors of performance, 2022, *Eurostat*, URL: https://ec.europa.eu/eurostat/web/products-datasets/-/tsc00003 (accessed 17.06.2022).

with a high influence of the higher education sector — the share of employment in the sector is about 50 % or more, and the others with less influence — the share of employment in the sector is less than 40 %. The first group includes the post-socialist countries of the EU: Poland, Estonia, Lithuania and Latvia, while the countries of the second group include Germany, Sweden, Denmark, Finland, Norway and Russia[9].

An analysis of employment in the private non-profit sector (Private non-profit sector — R&D (PNP)) did not reveal any significant patterns [31].

Among other things, all countries considered for the analysis of the labour resources of the STP sector can be divided according to the presence of two large groups: on the one hand, these are commercial structures, on the other hand, structures that carry out research and development not for profit (this is the public sector, the sector higher education and the non-profit sector) (Fig. 1). Thus, according to the structure of employment, the states of the Baltic region are also divided into two groups: countries having a market economy and post-socialist countries.

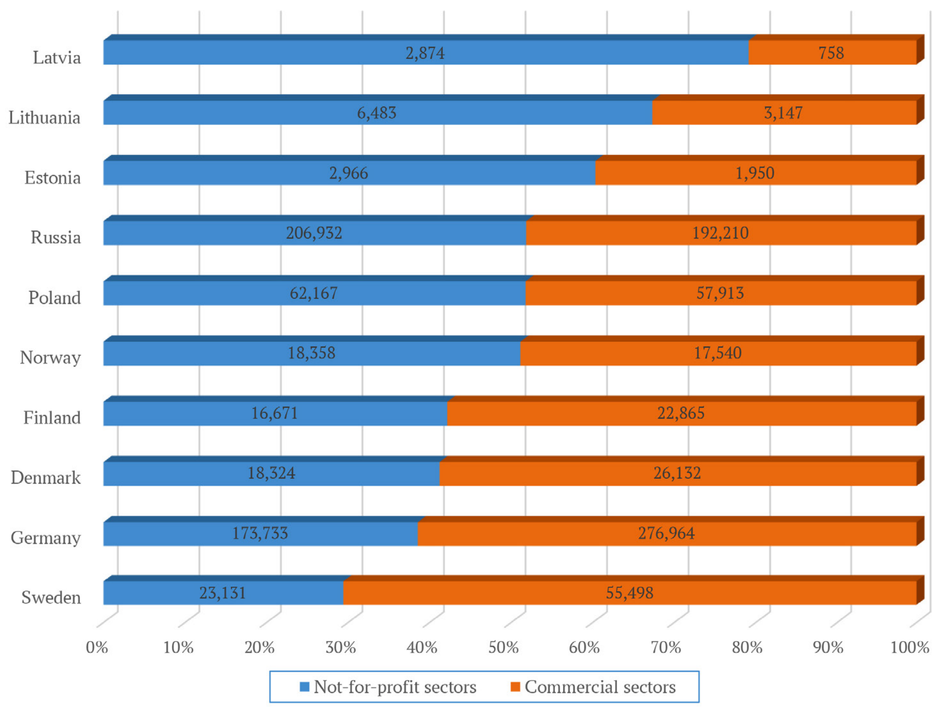


Fig. 1. The structure of employment in the commercial and not-for-profit sectors of science in 2019, people

[9] R&D personnel by sector of performance, professional position and sex, 2022, *Eurostat*, URL: https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSOCC/default/table?lang=en (accessed 07.02.2022).

## Results

The quantitative analysis of the scientific and technological landscape in the Baltic region has revealed two distinct groups of countries based on their fundamental characteristics. The first group, which comprises countries with a traditional market economy, exhibits a higher level of scientific and technological development. The second group, comprised of post-socialist countries, is characterized by a relatively lower level of scientific and technological development. This classification, though unsurprising, provides valuable insight into the scientific and technological landscape of the region.

Countries with market economies are distinguished by:

— high gross domestic spending on R&D (more than 2 % of GDP);

— a large number of researchers per 1000 people (more than five).

Post-socialist countries are characterized by:

— lower (less than 2 % of GDP) gross domestic expenditure on R&D;

— fewer researchers per 1,000 people (fewer than four) than in countries with a high level of scientific and technical development.

The analysis results of R&D funding and the state of labour resources can be subject to a more comprehensive interpretation by utilizing the graphic-analytical method (Fig. 2) and cluster analysis (Fig. 3), which allow us to distinguish the following two types — countries with traditional market economies and post-socialist countries.

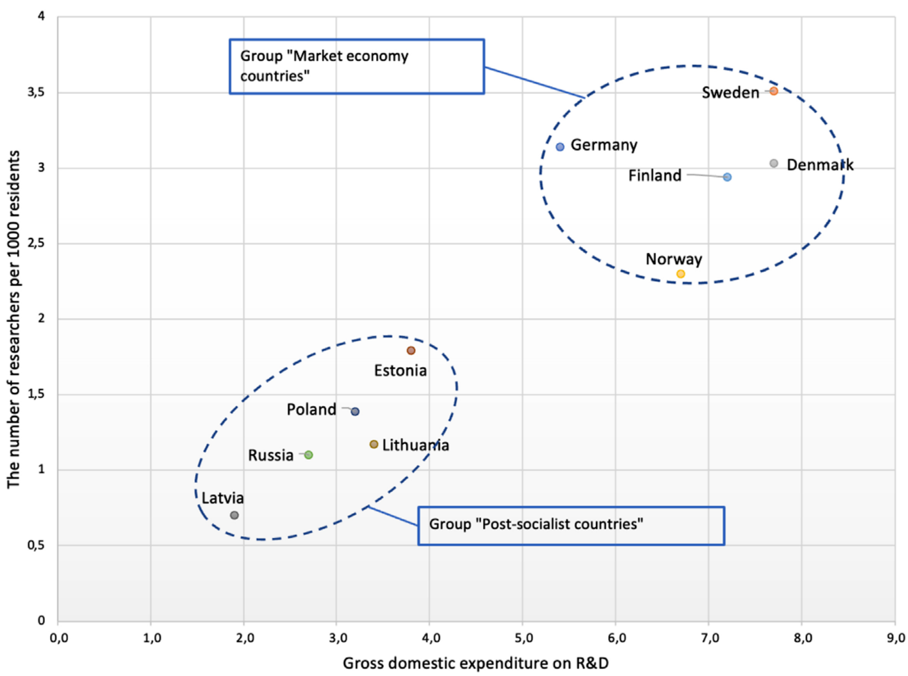


Fig. 2. Gross domestic expenditure on R&D and the number of researchers per 1,000 residents in the countries of the Baltic Sea region

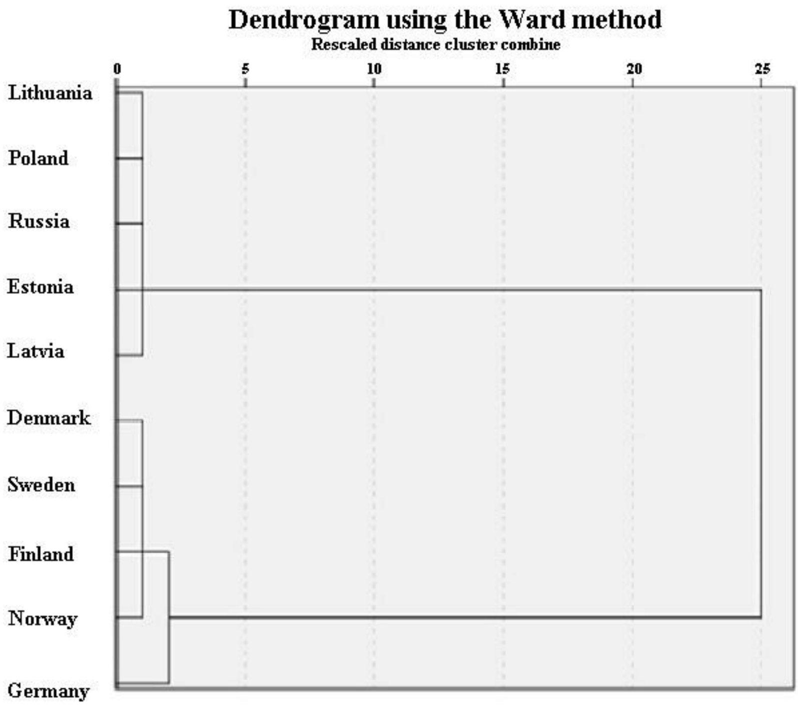


Fig. 3. Dendrogram of the classification of the countries
of the Baltic Sea region by gross domestic expenditure on R&D, % of GDP,
and the number of researchers per 1,000 residents

The application of the combined grouping method further enables the identification of subtypes within the selected countries. A detailed analysis of the growth rates of absolute R&D expenditures leads to the identification of three country subtypes: countries with high growth rates, including post-socialist EU countries such as Poland, Estonia, Lithuania, and Latvia; countries with moderate growth rates, including Germany, Sweden, Norway, and Denmark; and countries with low or negative growth rates, such as Russia and Finland (Table 4).

*Table 4*

**Growth rates of absolute R&D expenditure in 2010—2020, %**

| 90—180 | 30—55 | > 10 |
|---|---|---|
| Poland (179.7) | Germany (51.2) | Russia (8) |
| Lithuania (160.5) | Sweden (40.9) | Finland (–0.5) |
| Estonia (106.7) | Norway (35.5) | — |
| Latvia (91.6) | Denmark (33.3) | — |

*Note:* Bold type indicates market economy countries.

An analysis of the funding structure for research and development (R&D) allows for the identification of several subtypes based on the number of researchers employed in various sectors. The business enterprise sector (R&D (BES)) accounts for more than 50 % of R&D funding in Germany, Sweden, Denmark, Finland, Poland, and Estonia. On the other hand, the public sector, particularly the government sector (R&D (GOV)), is the leading investor in science in Norway and Russia, with more than 40 % of funding originating from this sector. In countries with a traditional market economy other than Norway and Russia, this figure is less than 30 %, whereas for the post-socialist EU countries (Poland, Lithuania, Estonia, and Latvia), this indicator is significant and ranges from 30 % to 40 %.

An important role in R&D funding is played by the foreign sector (FOR R&D) in the Baltic countries (Estonia, Latvia and Lithuania) and Finland — more than 10 %, in Poland, Sweden, Norway, Germany and Denmark it varies between 5—10 % and is completely insignificant for Russia. The indicator of R&D funding by the private non-profit sector (R&D (PNP)) is low. However, in the Nordic countries (Norway, Sweden, Denmark and Finland) it is more than 1 % with a tendency to slowly increase (Table 5).

*Table 5*

**Typology of the countries of the Baltic region according to the structure of R&D funding, %**

| Business enterprise sector — R&D (BES) | | Government sector — R&D (GOV) | | | Foreign sector — R&D | | | Private non-for-profit sector — R&D (PNP) | |
|---|---|---|---|---|---|---|---|---|---|
| > 50 | < 50 | > 40 | 30—40 | < 30 | > 10 | 5—10 | < 5 | > 1 | < 1 |
| **Germany** | **Norway** | **Norway** | Poland | **Denmark** | Lithuania | Poland | Russia | **Denmark** | Germany |
| **Sweden** | Lithuania | Russia | Estonia | **Germany** | Latvia | **Sweden** | — | **Sweden** | Russia |
| **Denmark** | Latvia | — | Lithuania | **Finland** | Estonia | **Norway** | — | **Finland** | Poland |
| **Finland** | Russia | — | Latvia | **Sweden** | **Finland** | **Germany** | — | **Norway** | Estonia |
| Poland | — | — | — | — | — | **Denmark** | — | — | Latvia |
| Estonia | — | — | — | — | — | — | — | — | Lithuania |

*Note:* Bold type indicates market economy countries.

An analysis of STP labour resources reveals that, with the exception of Latvia, Russia, and Finland, all countries are experiencing growth in the number of employed researchers. Particularly noteworthy is the substantial growth rates demonstrated by Poland, while significant growth is observed in Sweden, Germany, and Norway. Estonia, Denmark, and Lithuania are experiencing moderate growth in the number of researchers (Table 6).

*Table 6*

**Growth rate of the total number of researchers in 2010—2019, %**

| > 85 | 60—35 | 25—10 | > 0 |
|---|---|---|---|
| Poland (87.2) | **Sweden** (59.5) | Estonia (22.5) | **Finland** (– 3.5) |
| — | **Germany** (37.7) | **Denmark** (19.3) | Latvia (– 6.8) |
| — | **Norway** (35.7) | Lithuania (12) | Russia (– 9.4) |

*Note:* Bold type indicates market economy countries.

*Source:* Total researchers by sectors of performance, 2022, *Eurostat,* URL: https://ec.europa.eu/eurostat/web/products-datasets/-/tsc00003 (accessed 17.06.2022).

In post-socialist countries, the number of people who are employed in the commercial sector is smaller than in countries with traditional market economies. Russia is characterized by a high percentage of researchers employed in the government sector (R&D (GOV)), and a low percentage of those employed in the higher education sector (R&D (HES)). The states with high employment of researchers in the higher education sector include the post-socialist countries of the EU: Poland, Estonia, Lithuania and Latvia (Table 7).

*Table 7*

**Typology of the countries of the Baltic Sea region according to the structure of employment of researchers, %**

| Business enterprise sector — R&D (BES) | | | Government sector — R&D (GOV) | | | Higher education sector — R&D (HES) | | |
|---|---|---|---|---|---|---|---|---|
| > 50 | ~ 50 | < 50 | > 30 | 10—20 | < 10 | > 40 | 30—40 | < 30 |
| **Germany** | **Norway** | Lithuania | Russia | Estonia | Poland | Poland | **Norway** | **Germany** |
| **Sweden** | Russia | Latvia | — | **Norway** | **Denmark** | Lithuania | **Denmark** | **Sweden** |
| **Denmark** | Poland | Estonia | — | **Germany** | **Sweden** | Latvia | **Finland** | Russia |
| **Finland** | — | — | — | Latvia | **Finland** | Estonia | — | — |
| — | — | — | — | Lithuania | — | — | — | — |

*Note:* Bold type indicates market economy countries.

## Conclusion

The present study conducted an analysis of scientific and technological progress (STP) in various countries, with a particular focus on the Baltic Sea region. The study aimed to classify countries based on their level of STP development, taking into account a set of indicators that reflect different components of STP progress and sectors of activity. The results show that the Baltic Sea region has exhibited an upward trend in STP, with Poland being the only exception as it has undergone significant structural changes in this area.

Despite differences in dimensions, the studied countries can be grouped into two types based on their R&D funding and the condition of their STP labour force: countries with traditional market economies and post-socialist countries. The latter group is characterized by insufficient funding for STP and a lower level of research personnel development, which hampers their ability to compete on equal terms with the developed countries of the former type. It is worth noting that several decades have passed since the collapse of the socialist bloc, and yet, the identified types of countries have not reached a level playing field. Post-socialist countries went through economic and social upheaval following the fall of the 'people's democracy' regimes and the demise of the Soviet Union, which negatively impacted their STP progress.

Nevertheless, a closer examination of the data on funding structures and labour force revealed some differences. The post-socialist countries of the EU, namely Poland, Lithuania, Estonia, and Latvia, have shown high growth rates in absolute R&D expenses over the past decade. This trend can be attributed to their low initial levels of R&D funding and the significant weight of foreign funds in the general structure of R&D financing, which is especially characteristic of the Baltic States. On the other hand, traditional market economies (excluding Finland) have shown steady growth in absolute R&D spending. In contrast, Russia exhibits the lowest rate of growth in absolute R&D spending over the past decade, while Finland has experienced a slight decline.

The study also emphasizes the relationship between funding and labour resources in the STP sector, as increased investment in STP can improve the prestige of the researcher's profession and enhance the quality and efficiency of their work. The results indicate that Poland has maintained a consistent upward trend, whereas Sweden, Germany, and Norway have experienced substantial growth. On the other hand, Estonia, Denmark, and Lithuania have demonstrated a moderate level of progress. In contrast, Finland, Latvia, and Russia have experienced a decline.

Regarding funding structures and employment, Russia is notable for its high reliance on state funding, with the Higher Education Sector's role in employment for R&D being the lowest among the countries studied. To improve this situation, it is crucial to increase R&D funding by stimulating investments in the commercial sector (R&D (BES)), beyond public investment. Moreover, it is imperative to enhance the image of the research profession, with Germany serving as a good role model country that is comparable in size and past experience in overcoming the consequences of the socialist economy collapse.

Given the current geopolitical situation, Russia's effective participation in international cooperation and the international division of labour has temporarily slowed down. Therefore, interregional collaboration and closer ties with countries of the EAEU, SCO, and BRICS can become essential instruments for scientific and technological development.

Finally, the study will be further complemented by expert surveys and an analysis of the Baltic region's exports/imports traffic and patent activity. This approach will enable a characterization of the demand for the scientific and technological subsystem and the forecasting of its further development.

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