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STATISTICAL ANALYSIS OF 2022 RESEARCH AND DEVELOPMENT ACTIVITIES IN THE KUYAVIAN-POMERANIAN VOIVODESHIP

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Purpose: The purpose of the article is to analyze the state of 2022 research and development (R&D) activity in the Kuyavian-Pomeranian region, taking the structure of outlays, the sources of funding as well as the involvement of individual sectors and human capital into account. The study aims to assess the region's current standing, with reference to previous years, outlining its position relative to the entire country as well as identifying its R&D activity strengths and weaknesses.

Design/methodology/approach: The study's objectives have been achieved through the use of descriptive statistics methods, including structure analysis of location and dynamics measures. The focus was mainly on research and development (R&D) expenditure and personnel data for the Kuyavian-Pomeranian region. The data published by Poland's Central Statistical Office and the Patent Office of the Republic of Poland were used.

Findings: The analysis showed that R&D activity in the Kuyavian-Pomeranian region is characterized by increasing outlays, particularly in the business sector playing a dominant role both in terms of carrying out and financing R&D activities. Significant differences have been identified in the level of funding across individual fields of science, with the predominance of engineering and technical sciences accounting for over half of all outlays. The region, nevertheless, remains below the national average in terms of total R&D expenditures and the number of R&D personnel. What is more, the voivodeship has been noted to excel in its interdisciplinary approach to R&D activities, covering a broad spectrum of scientific fields, which presents an important advantage. High consumption of research equipment, however, as well as insufficient investment in such key areas as agricultural sciences and shortage of patent applications pose challenges to further innovation development in the region.

Originality/value: The article uniquely integrates statistical analysis with qualitative assessment, showing the dynamics and structure of R&D expenditures in the Kuyavian-Pomeranian region, within the context of its interdisciplinarity and innovation potential. One interesting solution consists in the synthetic presentation of changes in the voivodeship

data on R&D workforce in 2016-2022, using positional measures of location, with reference to the Kuyavian-Pomeranian voivodeship data in this context.

Keywords: research and development (R&D) activity, Kuyavian-Pomeranian voivodeship, statistical analysis.

Category of the paper: Literature review.

1. Introduction

Research and development (R&D) activity is a key component of modern economies, playing a vital role in innovative technology development, increasing competitiveness and generating economic advantage at the local and global levels. In the Polish context, regional variations in R&D expenditures, employment structure and resource efficiency are of particular importance. The Kuyavian-Pomeranian region, although not one of the leaders in terms of the scale of outlays, is characterized by interesting development dynamics and an interdisciplinary approach to R&D activity.

The present article analyzes the R&D activity in the Kuyavian-Pomeranian voivodeship both in 2022 as well as over the years, with focus on outlays, workforce and the effects of the activity, i.e., publications and patents. Descriptive statistics tools of structure analysis were used, in focus on central measures of the so-called position, taking a classical and positional approach. Dynamics analysis was carried out for the measures selected in the form of time series, using indices and calculations of the average rate of phenomena changes over time.

The article contributes conclusions of substantial relevance to regional R&D policy, indicating both the Kuyavian-Pomeranian region's strengths, such as interdisciplinarity and the dynamic development of the business sector, as well as its challenges, e.g., the shortage of funding for certain fields of science or the limited number of R&D personnel, compared to national leaders. The analysis presented comprehensively depicts the state of R&D in the region, which can serve as a valuable basis for further research and formulation of strategies to support R&D and innovation activity development at the regional level.

2. Evolution of the research and development sector in the Kuyavian-Pomeranian region

In the post-war years, the priority had been to rebuild the economy, which led to the emergence of the first scientific and industrial institutions of an R&D nature (Jarocińska, 2024; Wrochna, 2020). The origins of the research and development (R&D) sector in the Kuyavian-Pomeranian voivodeship can be traced to the activities of traditional academic centers and

scientific institutes, which had sprang up in the region as early as the 20th century. Universities, such as the Bydgoszcz University of Science and Technology (Politechnika Bydgoska im. Jana i Jędrzeja Śniadeckich), founded in 1951 as the *Evening School of Engineering*, or the Nicolaus Copernicus University in Toruń, founded in 1945, and the Kazimierz Wielki University in Bydgoszcz, founded in 1969, played a key role in educating specialists and conducting scientific research (Redakcja KIMP, 2023). The first research activities in the region were centered around traditional fields of science and technology, with support for the sector sourced mainly from the state budget. In the post-war years, the emphasis had been on the development of industry and technology, which fostered the development of research institutes collaborating with local businesses (Redakcja KIMP, 2023).

The post-1989 political transformation brought new challenges and opportunities for the R&D sector, as the introduction of a market economy called for changes in the structure of research funding and organization. The introduction of free market principles and the restructuring of industry led to far-reaching consequences, including the liquidation of numerous state research institutes, which until then had been the backbone of research for industrial purposes (Gryzik, Warzybok, 2012). The Kuyavian-Pomeranian voivodeship began to advance international cooperation and invest in modern technologies, which paved the way for a more dynamic development of R&D, especially after Poland's accession to the European Union in 2004. From that moment, the region's R&D sector began to benefit from EU funds, which allowed implementation of numerous research projects, development of scientific infrastructure, as well as greater cooperation of universities and research institutes with industry.

Initiatives supporting competitive research funding also began to emerge. The introduction of state and European-funded grants and programs contributed to increased interest in applied research. The emergence of programs to support innovation was particularly vital in the context of the developing market economy, with R&D coming to be viewed as a key element in the competitiveness of the economy (Plasek, 2016).

Those were also times of intense social change, increasing the demand for innovative products and technologies. As the market economy began to stabilize and foreign investment increased, new opportunities arose for the R&D sector in Poland. Foreign companies began to site their research centers in Poland, taking advantage of the availability of highly qualified scientific personnel, which sparked the development of the country's technology sector. The shift to competitive financing and access to European funds paved the foundation for the dynamic development of Poland's R&D sector in the 21st century (Popiński, 2022).

Since the country's accession to the European Union in 2004, Poland's R&D sector has received significant financial support from EU structural funds. Programs such as the 'Innovative Economy' (2007-2013) and the 'Intelligent Development' (2014-2020) Operational Programs have enabled the financing of R&D projects, supporting industrial innovation, technological development and cooperation between science and business.

The growth of the research and development sector in the Kuyavian-Pomeranian voivodeship is fostered by a number of regional strategies and programs. The key document is the *Economic Development Program for the Kujawsko-Pomorskie Voivodeship* [Polish: *Program rozwoju gospodarczego województwa kujawsko-pomorskiego*], serving as a roadmap for the implementation of comprehensive measures aimed at activating the region's economy, with emphasis on innovation and cooperation between science and business (Zarząd Województwa Kujawsko-Pomorskiego 2021b). In addition, the *Development Strategy for the Kuyavian-Pomeranian Voivodeship until 2030 - Acceleration Strategy 2030+* [Polish: *Strategia rozwoju województwa kujawsko-pomorskiego do 2030 roku - Strategia Przyspieszenia 2030+*] defines the goals and direction of the region's development, including in R&D, emphasizing the growth of economy innovativeness and development of entrepreneurship (Zarząd Województwa Kujawsko-Pomorskiego, 2021a).

The Bydgoszcz University of Science and Technology is one of the key players in the development of R&D sector in the Kuyavian-Pomeranian voivodeship. Its activities contribute to raising the level of innovation in the region, through the implementation of research projects, cooperation with industry, training of specialists and development of modern research infrastructure. The University operates as a technical university, providing engineering education with a focus on cooperation with industry, which is in line with the core assumptions of *Acceleration Strategy 2030*+.

3. Political framework for R&D sector development

In the past, the field of science and technology in Poland was segmented into three separate sectors: the Polish Academy of Sciences [Polish: Polska Akademia Nauk (PAN)], universities, and research and development institutes. Cooperation between these sectors was limited, while science funding was managed centrally, which contributed to bureaucracy and low efficiency. The so-called 'Law on Science,' introduced in January 1991, established three key principles: autonomy, recognition of scientific merit and openness. The coordination of science policy was entrusted to the State Committee for Scientific Research [Polish: Państwowy Komitet Badań Naukowych (KBN)], whose members and committees - in basic and applied research – were elected by the scientific community via two-round elections. The new model of research management and funding was aimed at more efficient utilization of budget funds for scientific activity in Poland (Karczewski, 1993). In his article: "Innovation policy during the transformation process in Poland: is it effective? [Polityka innowacyjna w procesie transformacji w Polsce: czy skuteczna?]", Professor Andrzej Jasiński distinguished 6 phases of innovation in 1990-2015, presented in the table below (Table 1).

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|---|---|---|
| 4 | 1 |) |

| | Phases of Poland's innovation policy in 1990-2015 | | | | | |
|-----------|---|---|--|--|--|--|
| Phase | Years | Policy characteristics | | | | |
| 1 | Through | In the late 1980s and early 1990s, a fairly broad set of financial incentives in the form | | | | |
| | 1990 | of legal solutions targeted at companies, especially small ones, was in place, | | | | |
| | | to stimulate those entities' research and innovation activities. | | | | |
| 2 | 1991-1994 | Under the so-called Balcerowicz Plan, with the widespread belief in the role of the | | | | |
| | | 'invisible hand of the market,' the vast majority of these stimulators were removed. | | | | |
| 3 | 1995-1999 | At the beginning of 1995, however, some of the 'old' incentives for R&D and | | | | |
| | | innovation activity were reinstate; the list of tax preferences was even quite extensive. | | | | |
| 4 | 2000-2004 | In early 2000, hamstrung by difficulties with the state budget, the number of incentives | | | | |
| | | was again reduced, and no new ones were introduced. | | | | |
| 5 | 2005-2007 | In 2005, following the accession to the European Union, several significantly new | | | | |
| | | solutions/instruments were introduced and some of the previous tax tools were | | | | |
| | | reinstated. | | | | |
| 6 | 2008-2015 | New instruments building on significant use of EU funds. | | | | |
| Courses L | acióalei 2010 | | | | | |

Table 1.

| Dhagog of innovation | malia in Dala | nd during i | 1000 2015 |
|-----------------------|-----------------------|-------------|-----------|
| I nuses of innovation | <i>poncy</i> in 1 oiu | na aaring 1 | 990-2015 |

Source: Jasiński, 2018.

Research and development (R&D) plays a key role in the shaping of innovative knowledgebased economies. The Triple Helix shift from the three elements of the so-called actors: science, industry, government to the concept of three areas: knowledge, innovation, consensus (government, local government) - highlights the significance of the environment and mutual interactions, placing R&D within the domain of knowledge (Jasiński, 2014). Appropriate targeting of innovation policy, both by the government and local authorities, is expected to advance R&D activities and secure knowledge transfer, which can take place bi-directionally between science and industry. Both the government and local authorities are responsible for the building of adequate research infrastructure, supporting innovative enterprises and stimulating cooperation between science and industry, enabling focus on R&D activity. Over the years, the significant role of regional centers has been recognized, and emphasis begun to be placed on the importance of harmonious cooperation between the government and regional authorities, which are able to adapt central government policies to region-specific, voivodeship conditions (Gust-Bardon, 2011; Czerniak, 2013; Churski, 2018). In the Polish context, the differences across regions in terms of innovation potential are considerable. Consequently, without dedicated programs to level out these differences, peripheral regions may find it difficult to achieve higher levels of R&D and innovation development. Synthetically, the Mazovian and Lesser Poland voivodeships are leaders in terms of Polish regions' innovativeness on a national scale (Instytut Badań nad Gospodarką Rynkową, 2024). The Kuyavian-Pomeranian voivodeship ranks 9th, with average and low scores in the various categories of innovativeness; the exception is enterprise R&D activity, rated highly, placing the voivodeship in the 5th place in this category alone. Overall, as a country, Poland ranks among the Emerging Innovators, nearing the European average (European Commission, 2023).

The National Science Policy [Polish: Polityka Naukowa Państwa] (2022) as well as the activities of the National Science Center [Polish: Narodowe Centrum Nauki (NCN)] and the National Center for Research and Development [Polish: Narodowe Centrum Badań i Rozwoju (NCBR)] provide the central mechanisms supporting the country's research activities, with the NCN focused on basic and the NCBR on applied research, enabling its commercialization and further experimental development (Journal of Laws 2024, item 1571, Article 4). Voivodship governments play a key role in adapting nationwide strategies to local conditions. It is these authorities which are responsible for the elaboration and implementation of regional research and development strategy (RDS), regional innovation strategy (RIS), and regional research and innovation smart specialization strategy (RIS3), which are intended to increase the innovative capacity of regions. RSI, RIS3 are operational documents based on a thorough analysis of the region's potential, the identification of key industries and the implementation of programs supporting R&D and innovation in sectors identified as most crucial (Golejewska, 2019; Ciołek, Golejewska, 2022). In the Kuyavian-Pomeranian voivodeship, for instance, special emphasis is placed on the development of innovation within the agri-food sector, in correspondence with the specificity of the region's economy. Smart specializations for the Kuyavia and Pomerania encompass: healthy and safe food, health and health tourism, advanced materials and tools, transportation and mobility, as well as cultural heritage and creative industries, with an emphasis on design (Zarząd Województwa Kujawsko-Pomorskiego, 2022). From the perspective of the regional policy implemented in the Kuyavian-Pomeranian voivodeship and the goals contained in Acceleration Strategy 2030+, it is essential to establish local partnerships among the science, business and administration sectors, to facilitate absorption of funds and implementation of research and development projects. Apart from the aforementioned food industry, of major importance for the region are the electrical machinery industry, the chemical and plastics processing industry, the pulp and paper industry, including wood processing.

4. The state of research and development activity in the Kuyavian-Pomeranian region throughout 2022

R&D outlays

• Key data on research and development activity in Poland

Gross domestic 2022 research and development outlays amounted to PLN 44702. 4 million, with the ratio to GDP reaching 1.46%. In per-capita terms, this value translates to PLN 1182. The number of R&D-registered entities in 2022 was 7431 - the highest in the preceding five years, 1585 of which financed their R&D activities with foreign funds, accounting for 21% of the total. Foreign funds as the share of GERD (Gross domestic expenditure on R&D), in turn, amounted to 8.1%. Intramural expenditures on R&D, financed from the 'rest of the world' sector, amounted to PLN 3625.3 million in 2022 (Statistics Poland, 2023).

The European Commission funds transferred to Poland for R&D in 2022 totaled PLN 2973 million, which is the highest compared to previous years (Figure 1). The share of European Commission funds in gross domestic outlays on R&D activity was only 6.7%, however. The number of entities benefiting from European Commission funds totaled 1417, accounting for 19.1% of all entities (Statistics Poland 2023).



Figure 1. European Commission funds financing R&D in Poland during 2018-2022.

Source: Own elaboration based on the "Research and experimental development in Poland in 2022" report, Statistics Poland, 2023, 10.10.2024.

• Intramural expenditures on R&D activity in the Kuyavian-Pomeranian voivodeship

The number of R&D entities by voivodeship is presented in Figure 2. The Kuyavian-Pomeranian voivodeship ranked in the second half of the list, with 340 registered entities, which is below average.



Figure 2. Number of entities in R&D, as of 31 December 2022.

Source: Own elaboration based on the "Research and experimental development in Poland in 2022" report, Statistics Poland, 2023, 10.10.2024.

In 2022, the Kuyavian-Pomeranian voivodeship was equipped with a scientific and research apparatus worth PLN 522538.5 thousand. The apparatus wear rate was 69.3%. Only 20% of all R&D entities in the region (68 out of 340) were equipped with scientific and research apparatus in a given year. The gross value of the voivodeship's apparatus, relative to the gross value of apparatus nationwide, is 2%.

The statistics on R&D activity include entities the main activity of which is assigned to subcategory 72 of the 2007 Polish Classification of Activities [Polska Klasyfikacja Działalności (PKD)], i.e., scientific research and development, as well as those entities which carry out R&D activities in parallel with other dominant activities. The key breakdown of R&D entities entails classification by executive sector, distinguishing between the business enterprise sector (BES), the government sector (GOV), the higher education sector (HES) and the private nonprofit institutions sector (PNI).

The 2022 intramural outlays on research and development in the Kuyavian-Pomeranian voivodeship reached PLN 1218116.3 thousand, of which PLN 246096.5 thousand were investment expenditures. The current expenditures thus absorbed as much as 80% of the total outlays (Figure 3). In breakdown by executive and financing sectors, the outlays formed as follows – see Table 1.



Figure 3. Intramural expenditures on R&D by cost type in 2022 (Kuyavian-Pomeranian voivodeship). Source: own elaboration based on Statistics Poland data, 25.10.2024.

The executive sector encompasses entities carrying out R&D activities directly, i.e., conducting scientific research and experimental development, therefore, the table shows R&D funding from these entities under the executive sector. The sector is the one responsible for carrying out practical research-project activities, by creating new technologies, conducting experiments, implementing innovations. In effect, specific research results, prototypes, scientific publications or new technologies emerge. The funding sector includes entities or organizations providing funds to carry out R&D activities without engaging in this part of research themselves. A given sector (e.g., business, higher education, government) simultaneously serves two functions within the R&D system. As an executive sector -

it implements a certain percentage of R&D activities, using funds to conduct research and development work. In other words, it engages in the actual execution of R&D projects. As a financing sector - it allocates a certain percentage of its funds to finance R&D activities carried out by other sectors. This can involve transferring of funds for research projects carried out by external institutions (e.g., universities, research institutes) or subsidizing of specific activities. Table 2 shows the value of outlays by sector and function, as well as the percentage ratio in the total amount of outlays in the Kuyavian-Pomeranian voivodeship.

Table 2.

2022 intramural expenditures on R&D by funding sectors and sectors of performance (Kuyavian-Pomeranian voivodeship)

| Sector | Outlay | vs value | Percentage in total outlays | | | |
|--------------------------------------|-------------|-----------|-----------------------------|-----------|--|--|
| | (in PLN 1 | thousand) | | | | |
| | Executive | Financing | Executive | Financing | | |
| enterprises (BES) | 781664 | 647261.8 | 64.17% | 53.14% | | |
| government (GOV) | 4881.8 | 433035.2 | 0.40% | 35.55% | | |
| higher education (HES) | 430683.8 | 33685.3 | 35.36% | 2.77% | | |
| private nonprofit institutions (PNI) | 886.7 | 1202.2 | 0.07% | 0.10% | | |
| rest of the world | - | 102931.8 | - | 8.45% | | |
| TOTAL | 1 218 116.3 | | 100% | | | |

Source: own elaboration based on Statistics Poland data, 10.10.2024.

The highest value of outlays, as an executive sector, was in the BES sector, i.e., the enterprise sector, amounting to PLN 781 664 thousand in 2022, accounting for as much as 64.17% of the total outlays in the voivodeship. Simultaneously, the enterprise sector likewise achieved the highest result as a financing sector (53.14% of the total outlays in the voivodeship). The higher-education sector, as an executor of R&D activities, covered 35.36% of total outlays, which is the second-highest result after the enterprise sector. Compared to the enterprise sector, however, it lags behind in equally high outlays as a financing sector, accounting for only 2.77%. The second-highest result, as a financing sector, was realized by the government sector (GOV) contributing PLN 433035.2 thousand to R&D activities, i.e., 35.55%. The 'rest of the world' accounted for only 8.45% of the value of total R&D funding.

Intramural R&D outlays can also be categorized by the type of activity. The distinction is made into basic research, applied research and experimental development. Table 3 shows the values for each type, in PLN thousands, including the percentage in the total outlays on R&D activities in the voivodeship. Moreover, notable is that basic research in the Kuyavian-Pomeranian region accounts for 3.6% of basic research outlays in Poland as a whole. Applied research, compared to the data on applied research outlays nationwide, equaled 1.2%. The remaining group, i.e., outlays on experimental development in the Kuyavian-Pomeranian voivodeship, totaled 2.7% of all outlays on experimental development in Poland.

| Expenditure on: (in PLN thousand) | | Percentage in total voivodeship expenditures | Percentage in total nationwide expenditures |
|--------------------------------------|----------|--|--|
| Basic research | 440864.2 | 36.2% | 3.6% |
| Applied research | 77252.9 | 6.3% | 1.2% |
| Experimental development | 699999.2 | 57.5% | 2.7% |

Table 3.

2022 intramural expenditures on R&D by type of R&D (Kuyavian-Pomeranian voivodeship)

Source: own elaboration based on data from Statistics Poland, 10.10.2024.

Figure 4 shows the breakdown of intramural outlays by the scientific fields in which the funds were implemented. Intramural R&D outlays include the expenditures incurred for the R&D carried out at the entity in the reporting year, regardless of the source of funding. They include current costs and R&D fixed asset investments, excluding depreciation. Consistent with the OECD (Organization for Economic Co-operation and Development) classification, these expenditures can be categorized into six main fields: natural sciences, engineering, medical, agricultural, social sciences, as well as humanities and the arts. R&D work consists of systematic creative activity aimed at expansion of knowledge and its practical application (Statistics Poland, 2023).

By far the dominant sciences are engineering and technical sciences, absorbing 57% of all outlays. Next are natural sciences (15%), humanities and the arts (9%), as well as social sciences (8%). Medical and health sciences rank merely fifth in the Kuyavian-Pomeranian voivodeship, with PLN 80205.1 thousand, i.e., 7% of the total. The least amount of funds was realized in agricultural and veterinary sciences - PLN 49235.9 thousand, i.e., 4% of the total R&D expenditures in the region under review.



Figure 4. 2022 intramural R&D expenditures by fields of R&D in (Kuyavian-Pomeranian voivodeship). Source: own elaboration based on Statistics Poland data, 20.10.2024.

Worth noting is the fact that not every voivodeship is outlayed in every R&D field. Apart from the Kuyavian-Pomeranian voivodeship, in 2022, the following are among those voivodeships: Lubusz, Lesser Poland, Masovian and Pomeranian. Although the KuyavianPomeranian voivodeship does not rank among the highest in terms of the value of R&D expenditures, it represents one of the five most interdisciplinary regions in terms of funds allocated to scientific activity. This, however, was not a year-to-year pattern, thus, in order to show the distribution of costs over the years, data for previous periods were collected (Table 4). Years in which the outlays equaled zero or the office, for some reason, failed to measure those values and enter the results in the database were noted (marked as: -).

Table 4.

Fields of R&D natural engineering medical and agricultural social humanities health and the arts sciences and and sciences technology sciences veterinary sciences in PLN million years 55.5 2008 33.8 0.0 5.7 2009 36.5 67.9 0.0 0.0 29.5 0.0 52.6 76.6 7.2 0.0 2010 79.1 0.0 0.0 11.6 2011 0.0 15.6 69.8 121.6 0.0 11.5 21.0 0.0 2012 2013 59.6 104.5 11.7 13.6 20.6 19.0 2014 46.4 156.5 14.6 8.2 16.1 13.9 2015 92.5 218.6 17.8 14.2 14.8 6.6 2016 40.2 181.6 22.0 9.5 17.5 19.2 2017 66.9 272.9 10.2 27.2 32.7 27.3 2018 94.2 340.6 61.9 16.9 44.7 47.9 2019 108.1 399.0 0.0 25.3 63.7 0.0 492.5 25.3 72.1 2020 126.5 0.0 0.0 2021 0.0 623.4 102 42.6 0.0 0.0 2022 188.6 679.5 80.2 49.2 94.6 108.0 Sum 1015.7 3869.8 350.1 224.6 436.9 26.,6

Analysis of 2008-2022 dynamics in intramural R&D expenditure changes in the Kuyavian-Pomeranian voivodeship, in distribution by field of science

Source: own elaboration based on Statistics Poland data, 22.10.2024.

The field of engineering and technical sciences shows annual average increases of 20% (4) (Figure 5), although years in which the outlays were lower than in the preceding year have also been noted, i.e., 2013 - a decrease by 14%, and 2016 - a decrease by 17% (Table 4).

$$T = \sqrt[15-1]{\frac{697\,471.7}{55\,444.8}} - 1 = \sqrt[14]{12.58} - 1 = 0.1982 \tag{1}$$

The field of medical and health sciences (Figure 6) repeatedly suffered a repeated failure to allocate financial outlays for research and development in the Kuyavian-Pomeranian voivodeship. The highest intramural expenditures were recorded in 2021, in the amount of PLN 102005.6 thousand.

Agricultural and veterinary sciences is another R&D field in which research and development expenditures have been increasing at an average annual rate of 17% (5). Only in 2009-2011 no values were recorded. These expenditures, however, reach the lowest values among all fields in the voivodeship.

$$T = \sqrt[15-1]{\frac{49235.9}{5647.5}} - 1 = \sqrt[14]{8.71} - 1 = 0.1673$$
(2)



Figure 5. 2008-2022 R&D expenditures in the Kuyavian-Pomeranian voivodeship – natural sciences & engineering and technology.

Source: own elaboration based on Statistics Poland data, 23.10.2024.



Figure 6. Expenditures on R&D in the kuyavian-pomeranian voivodeship in the years 2008-2022 – medical and health sciences & agricultural and veterinary sciences.

Source: own elaboration based on the data from Statistics Poland, 23.10.2024.

The data available for the field of social sciences begins in 2010. Throughout the following years, 2011-2016, R&D expenditures in this field of sciences were more or less leveled out. This is followed by several years of growth and a sudden drop to 0 in 2021. In 2022, however, R&D expenditures in this discipline reached an all-time high (Figure 7).



Figure 7. 2008-2022 R&D expenditures in the Kuyavian-Pomeranian voivodeship – social sciences, humanities and the arts.

Source: own elaboration based on Statistics Poland data, 23.10.2024.

• **R&D** expenditures over the years

The line chart presented (Figure 8) illustrates the dynamics of research and development (R&D) expenditure changes in the Kuyavian-Pomeranian region, from 2002 to 2022. An upward trend is evident, though with a few periods of decline, analyzed in detail in Table 5 via calculations of growth-rate and dynamics indicators.



Figure 8. 2002-2022 dynamics of intramural R&D expenditures in the Kuyavian-Pomeranian voivodeship.

Source: own elaboration based on Statistics Poland data, 20.10.2024.

From 2002 to 2016, periods of decline were recurring more or less regularly. In 2003, the outlays amounted to PLN 9.4 million less than in the previous year, indicating a decline of 8.5%. Another decline followed in 2005, and was lower than in the previous year, amounting to a 4.7% (PLN 5.7 million) reduction in the value of R&D expenditures. Two years later, the expenditures decreased by as much as 37.5%, from PLN 175.3 million to PLN 109.5 million. This decline was compounded by a reduction in the funds allocated from the budget and business entities. The crisis years in Poland showed increases. Year 2009 saw the largest increase in the analyzed period - by PLN 217.4 million, i.e., 168% of the 2008 amount. In 2010, however, the amount of research and development outlays decreased once again, by 41%. The downward trend recurred the following year, albeit with a lesser impetus, by 8.2%. It is the only time between 2002 and 2022 when the decline recurs a second year in a row. This was possibly caused by the crisis, which in the specifics of the analyzed characteristics is observable with a time lag. The 2013 outlays represent 75% of the value of the previous year's outlays. The last decline in the period under study, in turn, recurred in 2016 (Table 5).

Table 5.

| Analysis of 2002-202 | 2 dynamics o | f changes in | intramural R&D | expenditures |
|----------------------|--------------|--------------|----------------|--------------|
|----------------------|--------------|--------------|----------------|--------------|

| Year | [PLN million] | Absolute chain increase | Relative chain increase | Chain index |
|------|---------------|-------------------------|-------------------------|-------------|
| 2002 | 110.4 | - | - | - |
| 2003 | 101.0 | -9.4 | -0.0851 | 0.9149 |
| 2004 | 120.4 | 19.4 | 0.1921 | 1.1921 |
| 2005 | 114.7 | -5.7 | -0.0473 | 0.9527 |
| 2006 | 175.3 | 60.6 | 0.5283 | 1.5283 |
| 2007 | 109.5 | -65.8 | -0.3754 | 0.6246 |
| 2008 | 129.4 | 19.9 | 0.1817 | 1.1817 |
| 2009 | 346.8 | 217.4 | 1.6801 | 2.6801 |
| 2010 | 204.2 | -142.6 | -0.4112 | 0.5888 |
| 2011 | 187.3 | -16.9 | -0.0828 | 0.9172 |
| 2012 | 304.4 | 117.1 | 0.6252 | 1.6252 |
| 2013 | 228.9 | -75.5 | -0.2480 | 0.7520 |
| 2014 | 255.6 | 26.7 | 0.1166 | 1.1166 |
| 2015 | 364.4 | 108.8 | 0.4257 | 1.4257 |
| 2016 | 289.9 | -74.5 | -0.2044 | 0.7956 |
| 2017 | 437.1 | 147.2 | 0.5078 | 1.5078 |
| 2018 | 606.3 | 169,2 | 0,3871 | 1.3871 |
| 2019 | 721.5 | 115,2 | 0.1900 | 1.1900 |
| 2020 | 893.2 | 171,7 | 0.2380 | 1.2380 |
| 2021 | 1 162.1 | 268,9 | 0.3011 | 1.3011 |
| 2022 | 1 218.1 | 56 | 0.0482 | 1.0482 |

Source: own elaboration based on Statistics Poland data, 22.10.2024.

Years 2016-2022 is the period of the longest increase. The average rate of phenomenon change from 2016 to 2022 is 27%, meaning that, on average, research and development expenditures in the Kuyavian-Pomeranian voivodeship increased by 27% year on year. The value was calculated as follows:

$$T = \sqrt[n-1]{\frac{y_n}{y_1}} - 1$$
(3)

$$T = \sqrt[7-1]{\frac{1218.1}{289.9}} - 1 = \sqrt[6]{4,2} - 1 = 0.2702$$
(4)

i.e., after rounding off, presented as a percentage value of 27%.

Additionally, calculated was the average annual growth of R&D expenditures in the Kuyavian-Pomeranian voivodeship throughout the analyzed period, i.e., from 2002 to 2022:

$$T = \sqrt[21-1]{\frac{1218.1}{110.4}} - 1 = \sqrt[20]{11.03} - 1 = 0.1276$$
(5)

i.e., after rounding off, presented as a percentage value of 13%.

To better illustrate the scale of increases and decreases, a chain index chart was also plotted - with the base reference to the previous year. The value of outlays has been increasing successively in recent years. The smallest increase was observed in 2022, which amounted to merely 4.8%, compared to 2021. All chart values (Figure 9) below 1 indicate decreases relative to the previous year; all values above 1 suggest increases. An index taking a value equal to 1 represents an unchanged given characteristic in the following year, i.e., remaining at the same amount. The indexes can also be interpreted in percentage terms, e.g., in 2021 the index was 1.3011, meaning that the volume of outlays was 30.1% higher in 2021, relative to 2020.



Figure 9. Index notation with variable bases – 2002-2022 expenditures in PLN million in the Kuyavian-Pomeranian voivodeship.

Source: own elaboration based on Statistics Poland data, 21.10.2024.

Employment in the R&D sector

According to the Central Statistical Office [Polish: Główny Urząd Statystyczny (GUS)] data for 2022, the Kuyavian-Pomeranian voivodeship ranks eighth in the country in terms of the number of persons employed in the R&D sector. The data from 2016 onward covers the personnel directly involved in the R&D activities carried out at reporting entities, with a distinction between internal and external personnel, broken down into researchers and support staff. Taking researchers alone into account, the Kuyavian-Pomeranian region ranked 7th,

and 9th in terms of women in R&D. Relative to 2016-2020, this represents a two-to-three position leap in the ranking. Such a spectacular increase was prompted by the greater number of entities, which declared research and development work, reporting employees devoting a minimum of 10% of their time to R&D activities. Internal employees account for about 85% of all declared R&D personnel.

Figure 10 illustrates the distribution of internal R&D personnel by provinces in 2016-2022. For readability purposes, the chart shows no outlier observations (the Mazovian voivodeship, with the size of internal R&D personnel more than double that of the Lesser Poland voivodeship, ranked second). These data have instead been included in the calculation of central (location) measures, both classical and positional. Noted should be that the outliers, i.e., the extreme observations included in the calculation of the arithmetic mean (classical measure), ramp up the value of this parameter of distribution, thus it is worth using positional measures, such as a dominant feature and quartiles, in the interpretation. All the distributions obtained exhibit right-handed asymmetry, indicating that the arithmetic mean was reached by a small proportion of voivodeships. Half of the voivodeships are characterized by a number of employees well below the average, with the predominance of a small number of R&D personnel, up to 5 thousand employees. The number of R&D employees in the Kuyavian-Pomeranian voivodeship was below the average in all the years analyzed, and below the median in 2016-2020. Only in 2021-2022 this established value, splitting the collective in half, was exceeded, advancing the region to the top eight, i.e., to 7th position.



* Number of R&D employees (internal personnel) in the Kuyavian-Pomeranian voivodeship. x Average, Median.

Figure 10. 2016-2022 distribution of R&D personnel (internal personnel) in the Kuyavian-Pomeranian voivodeship.

Source: own elaboration based on Statistics Poland data, accessed: 21.10.2024.

Analysis of actual employee involvement in R&D work entails the use of data in FTE (full-time equivalent) measurement. On a per-FTE basis, i.e., full-time, 40-hour per week work in a given year, the Kuyavian-Pomeranian voivodeship ranked 9th in the country in 2022, which is an uptick by one position, compared to 2016-2021. Throughout the entire period under

study, the data on internal R&D personnel by FTE remain below the average and median values (Figure 11). Worth noting is that the dynamics of changes in the average is higher, compared to the median, which indicates a continuous increase in the disproportion across voivodeships, in absolute terms. On a relative scale, a 46.8% increase in R&D working time, from 111789.3 to 164098.7, was recorded in Poland in 2022, compared to 2016, while the average rate of changes was 6.61% year-on-year between 2016 and 2022. The Mazovian and Lesser Poland voivodeships proved to be the growth locomotives. The Kuyavian-Pomeranian voivodeship is catching up to the leaders at a rate of 8.8% year-on-year, which is the second result, after the Lower Silesian voivodeship at 9.43% year-on-year. Internal workers in the business sector (in FTE) are of key importance in the Kuyavia and Pomerania region, with a growth rate of 14.7% year-on-year during the period under review. In 2106, they accounted for 41.5% of all internal R&D personnel, and 56.9% in 2022.



* Internal R&D personnel by FTE in the Kuyavian-Pomeranian voivodeship.

Figure 11. 2016-2022 distribution of internal R&D personnel by full-time equivalent in the Kuyavian-Pomeranian voivodeship.

Source: own elaboration based on Statistics Poland data, 21.10.2024.

In 2022, R&D employees (in FTE) in the higher education sector of the Kuyavian-Pomeranian voivodeship accounted for less than 4.1% of the national total of university personnel engaged in R&D (9th position in the country). The indicators of the voivodeship's development, in terms of innovation (Zarząd Województwa Kujawsko-Pomorskiego 2022), include the number of researchers per 1000 economically active persons (in FTE) and R&D employees per 1000 economically active persons (in FTE). The benchmark values in 2019 were set at 3.6 and 4.6, respectively, with a target of 5 within the time horizon through 2029. In 2022, the indicators for the Kuyavian-Pomeranian voivodeship were precisely 4.2 and 4.6 (based on Statistics Poland data, 21.10.2024).

x Average, Median.

5. Effects of research and development activity

The National Research Institute [Polish: Państwowy Instytut Badawczy] published a report titled "Nauka w Polsce 2023 (Science in Poland, 2023)," collating, inter alia, the numbers of scientific publications reported in 2018-2022 by voivodeship (Figure 12) and the numbers of scientific articles published in the most prestigious journals in 2019-2022, including the percentage thereof in the total number of articles by voivodeship (Figure 13). The number of scientific publications in the voivodeship accounts for up to 5% of the total number of publications in Poland, and amounts to 18237 throughout the analyzed years 2018-2022. By contrast, the number of articles published in prestigious journals during those years is 2825, ranging between 30% and 40% of the total number of publications in the region.



Figure 12. Number of scientific publications reported in 2018-2022 by voivodeship.

Source: Information Processing Center. National Research Institute [Polish: Ośrodek Przetwarzania Informacji. Państwowy Instytut Badawczy], Nauka w Polsce 2023 (Science in Poland, 2023).



Figure 13. Number of scientific articles published in most prestigious journals throughout 2019-2022 and the percentage in total articles by voivodeship.

Source: National Research Institute [Polish: Ośrodek Przetwarzania Informacji. Państwowy Instytut Badawczy], Nauka w Polsce 2023 (Science in Poland, 2023).

Research and development activity leads to increased knowledge and its utilization in new application, whereby protection of the rights to intangible assets arising from scientific, research, development and economic activity becomes crucial. The system ensuring such protection of rights and reporting in this regard is overseen by the Patent Office of the Republic of Poland [Polish: Urząd Patentowy Rzeczypospolitej Polskiej (UPRP)]. According to the data presented in annual reports, the Kuyavian-Pomeranian voivodeship is characterized by poor results with respect to the protection of industrial property objects: inventions, utility models, industrial designs, trademarks. Voivodeship data by the categories reported and granted by the Office are presented in Table 6.

| Kuyavian-Pon | neranian voivodeship | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|------------------------------|----------------------|------|------|------|------|------|------|------|------|
| Domestic application | patents | 167 | 141 | 135 | 159 | 171 | 103 | 104 | 132 |
| | utility models | 79 | 52 | 49 | 76 | 44 | 48 | 31 | 22 |
| | industrial designs | 37 | 40 | 116 | 58 | 57 | 43 | 30 | 25 |
| | trademarks | 470 | 466 | 375 | 398 | 485 | 521 | 429 | 466 |
| Granted rights of protection | patents | 105 | 90 | 93 | 100 | 68 | 101 | 92 | 70 |
| | utility models | 29 | 28 | 52 | 34 | 42 | 39 | 35 | 22 |
| | industrial designs | 28 | 22 | 110 | 58 | 39 | 48 | 32 | 20 |
| | trademarks | 239 | 453 | 362 | 298 | 211 | 484 | 358 | 331 |

Table 6.

2016-2023 domestic application and protection of granted industrial property object rights (Kuyavian-Pomeranian voivodeship)

Source: own elaboration based on the Patent Office of the Republic of Poland data, 14.10.2024.

Analysis of the Kuyavia and Pomerania data collected provides no basis for formulating an opinion that the region's standing in terms of industrial property has been improving. There are no clear trends observable, and a certain time lag from the filing for and receipt of rights protection should be taken into account. The most time-consuming, labor-intensive and costly is the procedure involved in obtaining a patent, followed by the so-called 'small patent,' i.e., utility model, which takes up to 3 years. Registration of an industrial design spans over six months and costs roughly PLN 5000 for the entire 5-year protection cycle. Of relevance is also the period of protection, which in the case of trademarks extends over 10 years, with the possibility of renewal; for utility models it likewise covers 10 years, whereas for industrial designs, the period is 25 years, subject to cyclical payments. Considering such key data as filed inventions and received patents, as well as filed and protected utility models, the Kuyavian-Pomeranian voivodeship ranks much better than other regions in utility models, falling consistently within the top eight, ranking typically at 5th or 6th place. Patents generally rank 11th.

6. Conclusion

Analysis of the 2022 data shows that, although the Kuyavian-Pomeranian voivodeship lags behind the top regions in terms of total R&D expenditures, it stands out with its significant interdisciplinarity and efficient allocation of resources to a variety of scientific areas. Investments cover six key scientific fields (predominantly engineering and technical sciences), which allows for development of diverse research projects addressing both regional and national needs. The pursuit of interdisciplinarity promotes increased cooperation among various research centers and economic sectors.

The field of agricultural and veterinary sciences, despite its significance to the agriculturally oriented region, receives the least outlays of all the fields analyzed. Increased investment in this area could foster local innovation and competitiveness of the agri-food sector.

R&D expenditures in the region flow from a variety of sources, including the business sector, the government sector, higher education and foreign funds. Between 2002 and 2022, the voivodeship saw a steady increase in R&D investment, with particularly strong growth in recent years, supported by the public and private sectors. The business enterprise sector (BES) plays a key role both as a contractor and as a funder of R&D activity, which highlights the importance of industry-science cooperation and pinpoints the key role of the BES in the region's innovation development.

Although basic research accounts for a significant portion of the voivodship's outlays (36.2%), the share of applied research and experimental development (a total of 63.8%) remains insufficient, relative to industry needs. A strengthening of these areas could accelerate implementation of research results into business practice.

In 2022, the number of entities conducting R&D activity reached 340, which is a significant increase, compared to previous years. The increase in the number of entities declaring R&D activity indicates the region's growing efforts in this area.

The value of R&D apparatus in the region accounted for only 2% of the national value in 2022. The high degree of apparatus wear (69.3%) is indicative of the urgent need for investment in research infrastructure modernization.

While the voivodeship ranks 8th in the country in terms of the number of R&D employees, this value still fails to meet the needs of the sector. Measures should be taken to increase the number of qualified professionals, including initiatives to attract young scientists to the region. Although the region ranks 9th in the country in terms of the share of women in R&D activity, an upward trend is noticeable in this area. Promotion of gender equality in science and technology should receive priority in regional development strategies.

The executive sector is focused on research implementation, while the funding sector provides funds to conduct this research. The executive sector engages in practical R&D activities. The financing sector provides the financial and organizational conditions for R&D activity. Dominant in the executive sector are such research entities as universities and institutes. The funding sector includes governments, international organizations, foundations and private investors. The funding sector supplies resources and strategic support, while the executive sector transforms these resources into practical results, such as innovations, publications or new technologies. Cooperation between these sectors is essential for effective development of science and technology.

Achievement of the Acceleration Strategy 2030+ and smart specializations (RIS3) goals is crucial to increasing the region's innovativeness. The support for the R&D sector should be closely tied with identification of the region's local needs and strengths.

The Kuyavian-Pomeranian voivodeship holds the potential for further advancement of the R&D sector, nonetheless, it requires more sustainable investments, reinforced scientific personnel and intensified international cooperation. One key element will entail implementation

of innovative strategies and establishment of synergy among science, industry and administration.

The Kuyavian-Pomeranian voivodeship remains below the national average in several key indicators, such as the number of R&D employees or the per-capita value of outlays. Dedicated equalization programs are in demand, to help reduce the disparity to more developed regions such as the Mazovia and Lesser Poland.

Continued investment in R&D infrastructure is crucial to maintaining positive trends. The strengthening of the science, industry and government partnerships can increase the efficiency of research results commercialization. Further efforts should be geared towards developing the R&D personnel's competencies, as well as attracting talent through training programs and incentives.

Ongoing support for the R&D sector in the Kuyavian-Pomeranian voivodeship is essential for its development and increased competitiveness, in the context of a knowledge-based economy.

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