ARTICLES

CENTRAL EUROPEAN REVIEW OF ECONOMICS & FINANCE
Vol. 45. No 4 (2023) pp.5-25
DOI https://doi.org/10.24136/ceref.2023.020

Katarzyna Brożek[1]
Katarzyna Sieradzka[2]

INTELLECTUAL CAPITAL AND INNOVATIVENESS OF ENTERPRISES IN POLAND IN COMPARISON WITH THE EUROPEAN UNION COUNTRIES

Abstract

The development of enterprises mostly depends on their innovation. Intellectual capital is one of the factors in building the innovative potential of enterprises. The aim of the article is to analyze and evaluate the impact of intellectual capital on the innovativeness of enterprises in Poland compared to the European Union. The article utilized a critical analysis of the literature on the subject, while the empirical section employed statistical analysis, which included a characterization of the sample's selected features, analysis of a series of Pearson correlations examining the linear interdependence of features, and an examination of the obtained results. Data were obtained from the European Statistical Office for the years 2012-2021. The gathered data were processed using descriptive statistics – mean values, changes in dynamics, and Pearson correlation coefficient.

Key words: intellectual capital, enterprise innovation

JEL classification: D230, O310

[1] Phd., Jan Kochanowski University of Kielce, Faculty of Law and Social Sciences, e-mail: katarzyna.brozek@ujk.edu.pl
[2] Phd., Casimir Pulawski Radom University, Faculty of Economics and Finance, e-mail:k.sieradzka@uthrad.pl

Paper type: Theoretical research article

Introduction

The modern economy is characterized by high turbulence, while increasing competition in the market forces a concentration on intangible and unique resources, including knowledge. It is an essential factor, both from the perspective of enterprise development and the entire economy. One of the most important factors for improving the competitiveness and development of enterprises is and will be innovation, whose role is particularly significant in the currently changing environment (COVID-19 pandemic, armed conflict in Ukraine). Maintaining the competitive position of enterprises requires the implementation of broadly understood innovations. A factor significantly influencing the increase in the level of innovation of enterprises is intellectual capital, defined as the sum of human capital (which the employee takes with him - knowledge, skills and protected knowledge) and structural capital (owned by the company - knowledge and culture of the organization, protected knowledge) (Edvinsson, Malone, 2001, pp. 17-18). Statistical studies have proven that human capital is the main contributor to the success of a company, and its poor management is the cause of failure (Szopik-Depczynska, Korzeniewicz, 2011, p. 178). It is indicated that the survival of the company depends on the proper use of the intellectual capital of the enterprise for innovation, competitiveness and sustainable development (Githaiga et al. 2023, p. 41, Alvino et al., 2020, pp.76-94).

Human capital is understood as the knowledge, skills, qualifications, and experience, as well as the attitudes and behaviors of employees who create innovations. Employees represent immense value for a company and are perceived as a capital that should be developed (Juchnowicz, 2011, p. 85), while the lack of appropriate practices supporting human capital management can be a barrier limiting the innovativeness of enterprises (Beck-Krala, Duda, 2014, p.13). Indicators and measures of innovation suggest that despite investments made for this purpose, the level of innovation in Polish enterprises, as well as the entire economy, is low (EIS, 2022). According to the European Innovation Ranking in 2022, Poland ranked 4th from the bottom, placing in the last group of so-called emerging innovators. The European Commission indicates that innovation is the engine of economic growth in Europe. It is indicated that every euro invested in Horizon Europe's research and innovation program is capable of generating 11 euro of GDP over twenty-five years. The European Commission forecasts that between 2021 and 2027, investments in research, development and innovation will generate 11000 jobs in the research and high-tech sector (Jagodka, 2019, p. 25). The European Commission, analyzing the results of the 2022 EIS, indicated comments and recommendations for Poland in the area of innovation. These include (EC, 2022): predominance of the low-tech sector (low level of innovation generation and absorption), significant regional differences in the aspect of innovation, fragmented research sector, problems of internalization of Polish science, low level of spending on research and development (1.39% of GDP), also among enterprises (well below the EU average at 0.87% in 2020), small share of innovative companies in the enterprise sector. An accentuated problem is the low level of innovativeness of small and medium-sized enterprises in Poland, which is due to limited financial resources and problems in the application of high technologies, as well as the low level of management, which is related to the limited possibilities of obtaining appropriately educated and experienced management staff.

The aim of the article is to analyze and assess the impact of intellectual capital on the innovativeness of enterprises in Poland compared to the European Union. The article sets the following research hypothesis: there is a statistically significant relationship between the innovativeness of enterprises and the intellectual potential of EU countries. To verify the hypothesis, the article employs a critical analysis of the literature on the subject, while the empirical section utilizes statistical analysis of data acquired from the European Statistical Office (Eurostat) for the years 2012-2021. This analysis includes a characterization of the sample's selected features, an examination of various correlations examining the alignment of features, and an analysis of the obtained results. The gathered data were processed using descriptive statistics – mean values, changes in dynamics and the Pearson correlation coefficient.

1. Intellectual capital and enterprise innovation

Innovativeness determines the development and success of modern organizations. The search for and implementation of changes, which are synonymous with innovation, not only shapes the development of an economic entity, but also determines its survival in an ever-changing environment. Innovation, which is a manifestation of the use of scientific and material potential, stimulates progress in all spheres of socio-economic life. Views on the issue of innovation vary, but all approaches emphasize the element of novelty (Farazmand, 2004, Grudziewski, Hejduk, 2000). The precursor of the concept of innovation in the economic literature is J. Schumpeter (1960), who also pointed out that the willingness and ability to create and implement innovations determines the development of an enterprise, to a greater extent than capital, and therefore constitutes its innovation. It should be noted that innovation processes are complex in nature, as they involve not only the use of existing knowledge and the implementation and actual use of new ideas, but also the creation of new value.

The innovative activities of enterprises are conditioned by many factors, which are dynamic in nature and are most often categorized into internal and external ones. Among the external factors over which the enterprise has no control are: (Rychtowski, 2004, p. 589): administrative and legal conditions, socio-political climate, general market conditions, market and non-market linkages and technical infrastructure. Along with the changing socio-economic and political situation, external factors also include: the development of information and communication technologies, international exchange of scientific and technical achievements, the development of the national innovation system, and institutional conditions for the development of innovative activities, the growth of the service sector, including innovation financing and knowledge transfer. Contemporary innovation policy should be based on technology diffusion, network cooperation, knowledge, and the potential of human capital (Beck-Krala, Duda, 2014, p.14).

In the era of a knowledge-based economy, internal factors constitute the primary impetus for the development of organizational innovativeness. (Drews, 2018, p.83). These include (Radomska, 2015, p.73-74): physical resources, capital resources, human resources with the experience and skills necessary to create, absorb and apply innovations, the management system and organizational culture in the enterprise. Skills of individuals making managerial decisions in the company remain crucial for the development of innovativeness. These skills include: (Dworczyk, Szlasa, 2001, pp. 177-180): identifying innovation needs for all types of innovation, preparing a set of projects and its optimization by management, directing the implementation of individual projects, designing innovative solutions, implementing innovative projectsand products, increasing research and development potential, information potential, increasing innovative personnel potential and its use, providing technical potential for design, experimentation and prototyping, providing financial resources for innovative activities and managing them appropriately, using the innovative potential of the staff. The mentioned conditions for the development of innovativeness in enterprises significantly relate to human capital and the creation of appropriate conditions stimulating its creativity, creative thinking, and innovativeness. (Sieradzka, 2022). Modern market requirements oblige continuous education and acquisition of knowledge by employees, so human capital is a key resource in creating innovativeness of enterprises. Human capital creates innovative solutions in various fields and plays a key role in the creation of an organization's intellectual capital.

There is no one-size-fits-all definition of intellectual capital in the literature (Manzari et al., 2012, pp. 2255-2270). It is understood as the sum of knowledge possessed by the people who make up an enterprise's community and the practical transformation of this knowledge into components of its value. This capital is the difference between the total value of the enterprise and the financial value (Szopik-Depczyńska, Korzeniewicz, 2011, p. 193, Yang, Lin, 2009, pp. 1965-1984). It is the created wealth, formed from the knowledge of the employed employees of the enterprise involved in the constant process of increasing its value (Ujwary-Gil, 2010, p. 92). It is pointed out that intellectual capital is an invisible resource of an enterprise that creates visible effects (Urbanek, 2007, p.38). It is a compilation of knowledge, practical experience, technology, good customer relations and all the skills that allow a company to gain a competitive advantage (Weqar et al., 2023). Intellectual capital is defined by pointing out its three main elements: human capital, organizational capital (called structural capital) and customer capital (called by various authors: customer capital, market capital, relational capital) (Asare et al., 2021, p. 56, Szulczynska, 2005, p. 236, Sokolowski, 2018, p. 23). Human capital is understood as a human-integrated element, it includes knowledge, experience, skills and individual competencies of employees (Wequar et al., 2021, pp. 1134-1151). It is the source of knowledge creation and is the most important element of intellectual capital (Beyer, 2017, p. 87). It is a form of capital as it represents a source of present and future income. However, unlike other forms of capital (physical and financial), human beings cannot allocate portions of human capital among different uses. Therefore, the opportunity cost of using human capital always pertains to the entire resource of capital (Tyc, 2005, pp. 129-136).

The other elements of intellectual capital are not insignificant for the development of a company's innovation activities. Structural capital refers to the infrastructure that supports human capital and its effective use: management philosophy, organizational culture, management processes, information system, linkage system and financial relations, and intellectual property rights (Szulczynska, 2005, p. 236). It is the element of intellectual capital that remains in the company when employees go home (Gosh, Mondal, 2009, pp. 369-388). A company's assets can significantly improve its innovation capacity - information systems, information technology or processes facilitate the use and adoption of innovations in the company (Mention, 2012, p. 25). Organizational capital can foster the search for and implementation of new solutions and condition innovative activities. On the one hand, information systems, technologies facilitate the use and absorption of innovations, on the other hand, the appropriate organizational structure and culture allow the free transfer of knowledge in the organization (Beyer, 2017, p. 88). Market (relational) capital, which connects human and structural capital with external parties, is defined as all formal and informal relationships of a company with customers, shareholders and suppliers (Stefanska et al., 2019). Building ties with customers, creating better connections with strategic partners can increase the innovation performance of a company (Zelenrer et al. 2008, pp. 31-40). The important role of relational capital in the creation of incremental innovations is pointed out, while in combination with human capital it is possible to influence the emergence of radical innovations (Delgado, 2011).

2. Research Methodology

The aim of the article is to analyze and evaluate the impact of human capital on the innovativeness of enterprises in Poland compared to the European Union. In the theoretical part of the article, a critical analysis of the subject literature and a library query were utilized, while the empirical part employed statistical analysis, including a characterization of the sample's selected features, an examination of various correlations examining the alignment of features, and an analysis of the obtained results. Public statistics - the database of the European Statistical Office (Eurostat) was used as the data source. The gathered data were processed using descriptive statistics – mean values, changes in dynamics, median, first and third quartiles, and the Pearson correlation coefficient. The study of the relationship between human capital and innovativeness in EU countries used 5 arbitrarily selected predictors, which include:

- student to academic staff ratio,
- public spending on higher education,
- Human Resources in Science & Technology (HRST) aged 25-64,
- spending in the business sector on research and development (R&D),
- applications to the European Patent Office (EPO).

The selection of metrics for the study was guided by literature review and research intuition. The research period covered the years 2012-2021; however, due to incomplete data in public statistics, correlation analysis was conducted in slightly divergent research periods.

3. Intellectual capital and innovativeness – analysis of the results of an empirical study

The first indicator to be analyzed is the ratio of students to academic staff, 2013-2020 (Appendix, Table 1). Analyzing the average ratio of students to academic staff, from 2013 to 2020, it can be noted that the highest took place in Belgium (21.0), while the lowest in Luxembourg (6.2). In Poland, Austria and Portugal it was 14.3, and thus 11 EU countries achieved a higher average. According to the dynamics analysis, the highest positive change in the student-staff ratio was recorded for Cyprus (11.2 p.p.), while the lowest change took place in Spain (0.4 p.p.). A decrease in this indicator was observed in 14 countries, the most noticeable being in the Czech Republic (-5.7 p.p.), which can be interpreted positively in the context of this particular deterrent. In Poland, the change compared to 2013 was also negative, amounting to -2.1 p.p. Another variable analyzed from the area of human capital is the amount of public spending on higher education in the European Union in 2012-2019 (Annex Table 2). The highest positive change from the base year was in Bulgaria (0.14 p.p.), and the lowest positive change was in Romania (0.03 p.p.). The largest decrease in public spending on higher education was observed for Lithuania (-0.60 p.p.) and Latvia (-0.54 p.p.). In Poland, the difference was -0.05 p.p. In addition, it can be noted that especially the downward trend began in 2016, when the government in Poland changed and a number of social packages were introduced (e.g. 500+), which are an extremely heavy burden on the country's budget. Compared to other European Union countries, Poland ranks in the middle of the pack when it comes to spending on higher education. There were 11 countries that allocated a higher percentage of GDP to this purpose, with the biggest difference in the Scandinavian countries of Denmark (210.6% relative to Poland), Sweden (165.7% relative to Poland) and Finland (156.9% relative to Poland). Tertiary education, a lower percentage of GDP than in Poland, was allocated in 15 EU countries, with the lowest in Luxembourg (41.2% relative to Poland).

Another analyzed indicator is strictly related to innovativeness and concerns human resources in science and technology in EU countries in 2012-2021 (Appendix, Table 3). The results of the calculations show that between the initial and the compared year, changes in human resources in science and technology in each EU country were positive. The highest rate was recorded in Malta (15.4 p.p.) and Portugal (14.4 p.p.). The slowest rate of change was in Italy (2.5 p.p.), Romania (3.7 p.p.) and Finland (4.1 p.p.). In Poland, the percentage of human resources in science and technology increased by 9.6 p.p. between the first and last years analyzed. The average percentage of human resources in science and technology, in 16 countries was higher than in Poland, with the highest difference in Sweden (150.5%) and Luxembourg (147.2%). In contrast, a lower average was recorded by 10 countries. The largest disparity, in favor of Poland, was in Romania (60.7%) and Italy (78.7%).

The further study analyzed business sector R&D expenditures in 2012-2021 in European Union countries (Appendix, Table 4). In 2021, the highest R&D expenditures in the business sector were incurred by business entities from Sweden (1,249 euros per capita) and Belgium (1,053.5 euros per capita). The lowest expenditures were in Romania (35.9 euros per capita) and Latvia (40.2 euros per capita). In Poland, it was 137.6 euros per capita. The fastest growth in spending was observed in Cyprus (up 571.6%), followed by Poland (up 310.7%) and Lithuania (up 309.0%). A decrease in R&D spending in the analyzed sector was observed in only one country, Luxembourg (-8.6%). The ratio of average R&D expenditures to Poland was higher in 18 countries. The largest differences were in Sweden (1209.8%), Denmark (1052.1%) and Austria (1013.0%). In contrast, the largest disparity, in favor of Poland, was characterized by Latvia (28.0%) and Romania (28.6%).

The last predictor studied turned out to be the number of applications to the EPO between 2012 and 2021 among European Union countries (Appendix Table 5). Analysis of the dynamics of change in the number of applications to the EPO between 2012 and 2021 shows that 23 countries increased the number of patent applications. Lithuania (up 284.2%), Portugal (up 281.3%) and Bulgaria (up 207.7%) showed the highest growth. Poland was also among the countries that had positive dynamics, but in this particular case an increase of 40.0% was observed. The largest decline was in Cyprus (down 17.0%), followed by Romania (down 14.3%) and Latvia (down 12%). Germany (25,784) and France (10,530) had the highest average number of patent applications, during the period under review. The ratio of these countries to Poland was 5,242% and 2,140.8%, respectively, which is a significant disparity and shows the gap separating Poland from the EU innovativeness leaders. Poland recorded an average of approximately 492 patent applications, ranking 12th. Croatia, however, was the weakest in terms of patent activity (3.3% relative to Poland), followed by Latvia (3.8% relative to Poland), and slightly better by Bulgaria, Lithuania, Romania and Slovakia. However, it should be borne in mind that absolute values were analyzed for this measure; surely it would be more meaningful to compare relative values, if only in terms of the number of patents per capita of each EU country.

Conducting the above analysis allowed for the initiation of the next research task, which involved conducting Pearson correlation analysis. The r-Pearson correlation coefficient ($r_{x,y}$)[3] was selected for analysis because it allows us to determine whether there is a linear relationship between two variables – if so, it allows us to determine its strength and nature, i.e. whether it is positive or negative correlation[4]. Selected

[3] The formula for the r-Pearson correlation coefficient is: $r_{(x,y)} = cov_{(x,y)}/\sigma_x*\sigma_y$, wherein $cov_{(x,y)} = E(x * y) - (E(x) *E(y))$, where $r_{(x,y)}$ - r-Pearson correlation coefficient between variables x and y; $cov_{(x,y)}$ - covariance between variables x and y; σ - standard deviation from the population; E - expected value.

[4] The obtained relationships can be perceived as strong, moderate or weak; however, it seems that such an interpretation is arbitrary. Therefore, it was assumed that the strength of the correlation should be interpreted as follows: $|r_{x,y}| < 0.2$ – no linear relationship between the tested features; $0.2 \le |r_{x,y}| < 0.4$ – linear relationship clear but low; $0.4 \le |r_{x,y}| < 0.7$ – moderate relationship; $0.7 \le |r_{x,y}| < 0.9$ – significant relationship; $|r_{x,y}| \ge 0.9$ – very strong relationship.

indicators were correlated with each other, and the results, in descending order of the strength of the relationship, are presented in Table 1.

Table 1. Examination of the relationship between intellectual capital indicators and measures of innovativeness

X	Y	Years	Pearson's correlation coefficient
Human Resources in Science and Technology aged 25-64	Business sector R&D spending	2012-2021	0.699
Public spending on higher education	Business sector R&D spending	2012-2019	0.555
Public spending on higher education	Human Resources in Science and Technology aged 25-64	2012-2019	0.436
Student to academic staff ratio	Human Resources in Science and Technology aged 25-64	2012-2019	-0.235
Student to academic staff ratio	Business sector R&D spending	2013-2020	-0.185
Public spending on higher education	EPO filings	2012-2019	0.100

Source: own study and calculations.

A clear but low linear relationship was noted in the case of the relationship between Student to academic staff ratios vs. human resources in science and technology for 25-64 year old. The obtained result ($r_{x,y}$ ~ -0.24) indicates a negative correlation. In situations where one variable acts as a stimulant and the other as a destimulant (which is the case here), this relationship is rational and justified from an economic standpoint. A moderate correlation described two relationships, including: public expenditure on higher education and human resources in science and technology among people aged 25-64, where $r_{x,y}$ ~ 0.44, as well as public expenditure on higher education and expenditure in the business sector on R&D, where $r_{x,y}$ ~ 0.56. The strongest association, and therefore a significant relationship, was observed in the relationship between human resources in science and technology among people aged 25-64 and expenditure in the business sector on R&D, with $r_{x,y}$ ~ 0.7. In this case, both variables simultaneously increased or decreased - in the same direction, meaning that as human resources in science and technology expanded, business expenditure related to research and development also increased, and vice versa.

4. Discussion

A high student-to-teacher ratio is often cited as a critique of proportionally underfunded schools or educational systems, or as evidence of the need for legislative changes or increased education funding. Classes with too many students often disrupt the teaching process. In addition, overcrowded exercise/conversation groups result in varying degrees of learning ability. As a result, the group dedicates time to assimilating information for a smaller number of academic students, whereas this time could be used for research experiments or in-depth discussions on scientific issues. In this way, the student-to-teacher ratio serves as a compelling argument in favor of smaller class sizes. However, it's worth noting that in Finland, this ratio is higher than in Poland, yet the education system in that country is so well-constructed that it is recognized as the best in the world (Ustun, Eryilmaz, 2018, pp. 93-114). Therefore, the indicator presented is not the sole determinant that proves the quality of education, but it significantly affects it. E. Graue, et.al (2009, p. 178-201) drew attention to teacher-student interaction as an important aspect of good education and academic achievement. P. Blatchford and K.C. Lai (2012) and T.M. Dette and M. Raghav (2015) showed that smaller classes provide better teaching and learning. This approach has been observed in many countries including Japan and the United States. Nevertheless, the issue is ambiguous in the literature, as J. Keil and P.J. Partell (2002) showed that there is no relationship between class size and student retention. These issues are important because, as R. Mir-Babayev (2015, p. 75-80) stated, employees with higher levels of education improve innovation performance. Similar conclusions were reached by O. Toivanen and L. Väänänen (2016, pp. 382-396), who argued that people with engineering education have a positive impact on invention. This study found that the ratio of students to academics has a very weak relationship with human resources in science and technology, while it has an imperceptible relationship with R&D spending in companies.

A study conducted by B. Kwiek (2021, p. 31) notes that in Poland between 3% and 5% of universities will combine research and teaching missions. In addition, the author emphasizes that in universities, i.e. "In research-oriented positions, individuals perform exactly the same duties in the teaching dimension (following the same teaching workload) as in teaching-oriented positions. However, in research-oriented positions, there is an additional burden of research work, which is not imposed on teaching-oriented positions." (Kwiek, 2021, p. 10).

The study found a moderate relationship between public spending on higher education and human resources in science and technology. In her research, E. Pelinescu (2015, p. 184-190) tried to show the role of human capital as a growth factor. She showed a positive, statistically significant relationship between GDP *per capita* and innovativeness of human capital, as evidenced by the number of patents and employee qualifications. In turn, V. Linhartová (2020, p. 1-11) conducted a study to test whether public investment in areas that develop human capital can effectively support its development. It turned out that spending on education ranked only third in terms of its contribution to human capital development.

R. Villela and J.J. Paredes (2022, pp. 1-13) found that in spending on education, infrastructure and equipment are often overlooked. This is important, since the aforementioned elements are an important aspect in the development of innovation and the expansion of researchers. It is at the level of secondary and higher education that spending on infrastructure and equipment can encourage young people to conduct research. Education shapes individuals who have the potential capacity to innovate and change direction.

It is important to remember that education, which pertains to the way teaching and learning are organized throughout life, plays a fundamental role in societal transformations (UNESCO, 2021). Organizations such as the OECD (2021) and the UN (2022) have highlighted global challenges related to pandemics or military conflicts that may affect issues of science, technology, and innovation. Actions involve the need to increase the importance of science and technology in the economy and society, as well as the need to accelerate digital transformation, literacy skills, and the dissemination of access to technology and its use in various sectors, departments, branches, and industries of the national economy.

5. Conclusions

Changes in the external environment, including globalization, armed conflicts, pandemics, the development of new technologies, increasing customer demands, and the growing role of non-market instruments in competitive market battles, pose significant challenges for business development. They require continuous learning and new competencies from employees. Innovation policy increasingly includes the human factor among the factors determining the innovativeness of enterprises. Human capital creates innovative solutions and plays a key role in creating the intellectual capital of the enterprise. Intellectual capital, understood as a set of intangible resources and capabilities, has been recognized by many authors as a determinant of innovative activity and a source of the company's competitive advantage.

Based on the study, the following conclusions can be drawn:

1. The variable describing the student-to-academic staff ratio between 2013 and 2020 recorded a negative rate of change, which according to numerous studies may be a good sign. It is inferred that the size of student groups is decreasing, which may have a positive impact on the quality of higher education. However, despite this, Poland still has much ground to cover in this regard, as the obtained average only allowed it to be ranked 12th among the EU-27 countries. However a linear relationship clear but low was observed between this indicator and human resources in science and technology. But between this indicator and enterprise expenditure on R&D, it was no linear relationship.
2. A concerning issue seems to be the fact that between 2012 and 2019, public expenditure on higher education decreased. However, it should be emphasized that this was a pan-European trend. Such an approach may lead, in Polish educational institutions, to smaller investments in the already limited infrastructure and equipment, which in turn may have an indirect impact on the subsequent academic careers of students/graduates. A moderate strength of association was shown between public expenditure on higher education and enterprise expenditure on R&D, further reinforcing the above inference.
3. A positive aspect is that Polish enterprises increased their human resources in science and technology by almost one-third. Although this trend was observed in all EU-27 countries, in Poland, the upward trend was very pronounced. However, there is still a lot of catching up to do with EU innovation leaders, as the average human resources in science and technology ranked Poland in 17th place. It is worth noting that a moderate correlation was found between public expenditure on higher education and human resources in science and technology, which, given the research objective, should be considered an extremely important argument confirming the evident and significant impact of human capital on innovation in EU countries.
4. The largest increase in R&D and development in the business sector was observed in Poland. However, despite this, these expenditures were over ten times lower than in countries such as Sweden, Denmark, or Austria. It is important to pay special attention to this aspect because it has been shown that as enterprise expenditure on R&D increases, there is a corresponding increase in human resources in science and technology, and conversely.
5. An increase in the number of patent applications to the EPO by Polish entities has been observed, but their scale is still unsatisfactory. In strong knowledge-based economies, such as the German economy, this indicator was over fifty times higher than that describing the Polish economy. During

the conducted correlation analysis, no linear relationship was confirmed between public expenditure on higher education and the number of applications to the European Patent Office.

References:

1. Alvino F., Di Vaio A., Hassan R., Palladino R. (2020), *Intellectual capital and sustainable development: a systematic literature review*, „Journal of intellectual Capital", Vol. 22, No. 1.
2. Asare N., Laryea M.M., Onumah O.O., Asamoah M.E.. (2021), *Intellectual capital and asset qualityin an emerging banking market*, „Asian Journal of Accounting", Vol. 6, No. 1.
3. Beck-Krala E., Duda J. (2014). *Zarządzanie kapitałem ludzkim a innowacyjność przedsiębiorstw*, Przegląd Organizacji, No. 5(892).
4. Beyer K. (2017). *Rola kapitału intelektualnego w kreowaniu innowacyjności przedsiębiorstw*, Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania Uniwersytetu Szczecińskiego, No. 48/3.
5. Blatchford, P., Lai, K.C. (2012). Class size: arguments and evidence [w:] B. McGraw, E. Baker, P. P. Peterson (ed.), *International encyclopedia of education. Elsevier*, Oxford.
6. Delgado M. (2011). *The role of intellectual capital assets on the radicalness of innovation: direct and moderating effects*, UAM-Acenture Working Paper 2011/05 [za:] Różycka A. (2013). *Zarządzanie kapitałem intelektualnym a innowacyjność przedsiębiorstwa*, Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 786, Finanse Rynki Finansowe, Ubezpieczenia nr 64/1.
7. Dette, T.M., Raghav, M. (2015). Class Size Matters: Heterogeneous Effects of Larger Classes on College Student Learning. *Eastern Economic Journal, No. 41*.
8. Drews A. (2018). *External determinant sof innovative activity in Polish small enterprises*, Acta Universitatis Nicolai Caopernici, Zarądzanie nr XLV- No.1.
9. Dworczyk M., Szlasa R. (2001). *Zarządzanie innowacjami. Wpływ innowacji na wzrost konkurencyjności przedsiębiorstw*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa.
10. Edvinsson L., Mallone M. (2001). *Intellectual Capital: Realizing Your Companie`s True Value by Finding its Hidden Brainpower*, Harper Business.
11. Edvinsson L., Malone M.S. (2001). *Kapitał Intelektualny*, Wydawnictwo Naukowe PWN, Warszawa 2001.
12. European Comission – *Country – specyfic recommendations*, 2022, https://data.consilium.europa.eu/doc/document/ST-9769-2022-INIT/en/pdf [access date: 12.12.2022]

13. European Innovation Scoreboard, 2022, https://op.europa.eu/en/publication-detail/-/publication/418e3207-4b78-11ed-92ed-01aa75ed71a1/language-en/format-PDF/source-271491048 [access date 2.01.2023]
14. Farazmand A. (2004). *Innovation in Strattegic Human Resource Management:building Capacity in the Age of Globalization*, Public Organization Review, No 4.
15. Githaiga P.N., Soi N., Buigut K.K (2023). *Does intellectual capital matter to MFIs` financial sustainability*?, „Asian Journal of Accounting", Vol. 8, No. 1.
16. Gosh S., Mondal A. (2009), *Indian software and pharmaceutical sector IC and financial performance*, Journal of Intellectual Capital, Vol. 10, No. 3.
17. Graue, E., Rauscher, E., Sherfinski, M. (2009). The synergy of class size reduction and classroom quality. *The Elementary School Teacher, No. 110(2).*
18. Grudziewski W.M., Hejduk I.K. (2000). *Przedsiębiorstwo przyszłości*, Wyd. Difin, Warszawa.
19. Jagódka, M., (2019). *Problemy finansowania działalności innowacyjnej w Polsce*, Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, Vol. 63, No. 119.
20. Juchnowicz M. (red.). (2011). *Najlepsze praktyki w zarządzaniu kapitałem ludzkim*, OW SGH, Warszawa.
21. Keil, J., Partell, P.J. (2002). *The Effect of Class Size on Student Performance and Retention at Binghamton University,* https://www.classsizematters.org/wp-content/uploads/2012/11/Class_size_jkpp1997.pdf; [access date 19.12.2022].
22. Kwiek, M. (2021). Produktywność naukowa – uczelnie badawcze i ich kadra akademicka. *Raporty z Badań Centrum Studiów nad Polityką Publiczną UAM,* Poznań.
23. Linhartová, V. (2020). The Effect of Government Expenditure on Human Capital in the Czech Republic. *Scientific Papers of the University of Pardubice, Series D, No. 28(2).*
24. Manzari M., Kazemi M., Nazemi S., Pooya A. (2012), *Intellectual capital: conceps, components and indicators: a literature review*, „Management Science Letters", No. 2(7).
25. Mention A.L. (2012), *Intellectual Capital, Innovation and Performance: a Systematic Review of the Literature*, „Business and Economic Research", Vol. 2, No. 1.
26. Mir-Babayev, R. (2015). *Impact of education on innovation performance: evidence from Azerbaijan construction industry*. "IOSR Journal of Business and Management", *No. 17(12)*.
27. OECD, (2021). *How will COVID-19 reshape science, technology and innovation?,* https://read.oecd-ilibrary.org/view/?ref=1098_1098772-

3qmm9rpta1&title=How-will-COVID-19-reshape-science-technology-and-innovation1630438326; [access date 27.12.2022].
28. ONZ, (2022). *Science, technology and innovation for sustainable development Report of the Secretary - General,* https://documents-dds-ny.un.org/doc/UNDOC/GEN/N21/207/67/PDF/N2120767.pdf?OpenElement; [access date 27.12.2022].
29. Pelinescu, E. (2015). *The Impact of Human Capital on Economic Growth*. "Procedia Economics and Finance", No. 22.
30. Radomska E. (2015). *Innowacyjność jako wyzwanie rozwojowe – uwarunkowania działalności innowacyjnej przedsiębiorstw*, Kwartalnik Naukowy Uczelni Vistula, No. 4(46).
31. Rychtowski S. (2004). *Zewnętrzne i wewnętrzne uwarunkowania innowacyjności a sytuacja przedsiębiorstw w Polsce*, Prace Naukowe Akademii Ekonomicznej we Wrocławiu, Wrocław, No. 1045.
32. Schumperer J. (1960). *Teoria rozwoju gospodarczego*, Wyd. PWN, Warszawa.
33. Sieradzka K. (2022). *Kreatywność i innowacyjność a kompetencje menedżerskie,* [w:] A.Wolak-Tuzimek (red.), *Uwarunkowania rozwoju przedsiębiorstw i gospodarki*, Wyd. Uniwersytetu Technologiczno-Humanistycznego w Radomiu, Radom.
34. Sokołowski J. (2018). *Kapitał intelektualny a innowacyjność przedsiębiorstwa*, „Zarządzanie innowacyjne w gospodarce i biznesie", nr 2(27).
35. Stefańska D., Bubel D., Barcik A. (2019). *Zarządzanie kapitałem intelektualnym w perspektywie nowego zarządzania publicznego,* Zeszyty Naukowe Politechniki Częstochowskiej, „Zarządzanie", No. 34.
36. Szopik-Depczyńska K., Korzeniewicz W. (2011). *Kapitał ludzki w modelu wartości przedsiębiorstwa*, Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania, Wydawnictwo Naukowe Uniwersytetu Szczecińskiego, No. 24.
37. Szulczyńska U. (2005). *Kapitał intelektualny w działalności innowacyjnej przedsiębiorstw*, Nierówności a wzrost gospodarczy, No. 7.
38. Toivanen, O., Väänänen, L. (2016). *Education and invention*. The Review of Economics and Statistics, No. 98(2).
39. Tyc W. (2005). *Kapitał ludzki jako zasób czynników wytwórczych*, [w:] Kopycińska D. (red.),. *Teoretyczne aspekty gospodarowania*, Katedra Mikroekonomii Uniwersytetu Szczecińskiego, Szczecin 2005.
40. Ujwary-Gil A. (2010). *Kapitał intelektualny – problem interpretacji kluczowych terminów*, Organizacja i Kierowanie, No. 2(140).
41. UNESCO, (2021). *Reimagining our futures together: a new social contract for education*. Report From The International Commission

On The Futures Of Education, United Nations Educational, Scientific and Cultural Organization, Fontenoy.

42. Urbanek G. (2007), *Pomiar kapitału intelektualnego i aktywów niematerialnych przedsiębiorstwa*, Wydawnictwo uniwersytetu Łódzkiego, Łódź.
43. Ustun, U., Eryilmaz, A. (2018). *Analysis of Finnish Education System to question the reasons behind Finnish success in PISA.* Studies in Educational Research and Development, No. 2(2).
44. Villela, R., Paredes, J.J. (2022). *Empirical Analysis on Public Expenditure for Education, Human Capital and Economic Growth: Evidence from Honduras*. Economies, No. 10(241).
45. Weqar F., Sofiego A., Haque SM.I. (2023). *Nexus between intellectual capital and business performance: evidence from India*, Asian Journal of Accounting (before printing), https://www.researchgate.net/publication/347371613_Nexus_between_intellectual_capital_and_business_performance_evidence_from_India [access date: 12.02.2023].
46. Wequar F., Khan A.M., Raushan M.A., Haque S.M.I. (2021), *Measuring the impast of intellectual capital on the financial performance of the financial sector of India*, „Journal of Knowledge Economy", No. 12.
47. Yang C.C., Lin C.Y.Y. (2009*), Does intellectual capital mediate the relationship between HRM and organizational performance? Perspective of a Healthcare industry in Taiwan*, „The International Journal of Human Resource Management", No. 20(9).
48. Zelenrer M., Hasiloglu S.B., Mete S. (2008). *Intellectual capital and innovation performance: Empirical evidence in the Turkish Automotive supplier*, „Journal of Technology Management & Innovation", Vol. 3, Issue 4.

Appendix: Table 1. Ratio of students to academic staff from 2013 to 2020 in the European Union

Country \ Year	2013	2014	2015	2016	2017	2018	2019	2020	M	Me	Q_1	Q_3	Structure [M Poland = 100%]	Changes to 2013 r. [p.p.]
Belgium	21,0	22,5	b/d	21,2	21,2	21,0	21,4	18,8	21,0	21,2	21,0	21,3	147,0	-2,2
Bulgaria	12,9	13,1	12,9	12,4	12,0	11,5	11,3	11,9	12,3	12,2	11,9	12,9	85,7	-1,0
Czech Republic	21,9	22,3	22,9	18,9	18,4	15,0	16,8	16,2	19,1	18,7	16,8	22,0	133,2	-5,7
Denmark	b/d	14,3	18,1	17,3	16,1	15,8	15,7	15,8	16,2	15,8	15,8	16,7	113,0	b/d
Germany	11,7	11,8	12,0	12,1	12,1	12,0	11,9	11,7	11,9	12,0	11,8	12,0	83,3	0
Estonia	b/d	15,1	14,0	13,7	13,5	12,8	12,9	12,2	13,5	13,5	12,9	13,9	94,1	b/d
Ireland	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d
Greece	b/d	44,5	39,8	39,6	38,7	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d
Spain	12,1	12,9	12,7	12,2	12,4	12,3	12,2	12,5	12,4	12,4	12,2	12,6	86,8	0,4
France	b/d	b/d	b/d	16,3	16,2	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d	b/d
Croatia	12,4	12,8	12,8	12,6	12,8	12,5	12,1	11,4	12,4	12,6	12,4	12,8	86,9	-1
Italy	19,0	18,8	20,2	20,2	20,0	20,3	20,2	20,8	19,9	20,2	19,9	20,2	139,4	1,8
Cyprus	14,3	17,3	17,2	17,1	20,9	22,0	22,5	25,5	19,6	19,1	17,2	22,1	137,1	11,2
Latvia	19,5	18,9	18,7	18,6	16,6	16,3	16,9	16,3	17,7	17,8	16,6	18,8	124,0	-3,2
Lithuania	16,6	16,1	16,5	16,3	16,2	14,4	14,5	15,0	15,7	16,2	15,0	16,4	109,8	-1,6
Luxembourg	b/d	b/d	8,2	7,6	7,2	4,4	4,9	4,8	6,2	6,1	4,9	7,5	43,2	b/d
Hungary	14,8	15,1	14,6	13,7	12,1	11,5	11,4	11,3	13,1	12,9	11,5	14,7	91,3	-3,5
Malta	10,3	10,0	9,6	9,5	9,4	9,0	9,0	8,7	9,4	9,5	9,0	9,7	66,0	-1,6
Netherlands	b/d	b/d	15,4	14,8	14,6	14,6	14,9	14,6	14,8	14,7	14,6	14,9	103,6	b/d
Austria	15,0	14,7	14,4	14,4	14,0	13,8	13,5	14,2	14,3	14,3	14,0	14,5	99,7	-0,8
Poland	15,1	15,2	14,9	14,6	14,3	13,8	13,5	13,0	14,3	14,5	13,8	15,0	100,0	-2,1
Portugal	14,0	14,4	13,9	14,4	14,2	14,3	14,5	14,6	14,3	14,4	14,2	14,4	99,9	0,6
Romania	21,2	19,6	18,7	19,3	19,4	19,8	19,4	19,8	19,7	19,5	19,4	19,8	137,4	-1,4
Slovenia	18,1	17,5	17,1	15,3	14,9	14,4	14,3	13,6	15,7	15,1	14,4	17,2	109,4	-4,5
Slovakia	13,8	13,7	13,0	12,4	11,9	11,4	11,3	11,4	12,4	12,2	11,4	13,2	86,5	-2,4
Finland	13,8	14,2	15,1	15,3	15,5	15,3	14,9	14,4	14,8	15,0	14,4	15,3	103,6	0,6
Szweden	11,0	10,7	10,4	10,4	10,3	10,1	10,0	9,9	10,4	10,4	10,1	10,5	72,4	-1,1
UE-27	**b/d**	**15,4**	**15,4**	**15,1**	**15,3**	**b/d**	**b/d**	**b/d**	**b/d**	**b/d**	**b/d**	**b/d**	**b/d**	**b/d**

Legend: M – arithmetic mean, Me – median, Q_1 – first quartile, Q_3 – third quartile, b/d – no data.
Source: Own analysis based on Eurostat, https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4283841/default/table?lang=en; [access date 15.12.2022].

Appendix: Table 2. Public spending on higher education 2012-2019 in the European Union [% of GDP]

Year / Country	2012	2013	2014	2015	2016	2017	2018	2019	M	Me	Q_1	Q_3	Structure [M Poland = 100%]	Change to 2012 r. [p.p.]
Belgium	1,43	1,50	1,49	1,45	1,44	1,47	1,49	1,53	1,5	1,5	1,5	1,5	130,2	0,1
Bulgaria	0,66	0,65	0,70	0,65	0,59	0,81	0,76	0,80	0,7	0,7	0,7	0,8	62,0	0,14
Czech Republic	1,05	0,88	0,80	0,77	0,70	0,70	0,92	0,93	0,8	0,8	0,8	0,9	74,5	-0,12
Denmark	b/d	2,28	2,35	b/d	2,63	2,39	2,35	2,31	2,4	2,4	2,3	2,4	210,6	b/d
Germany	1,28	1,27	1,27	1,25	1,26	1,25	1,27	1,28	1,3	1,3	1,3	1,3	111,8	0
Estonia	1,03	1,37	1,51	1,42	1,40	1,13	1,18	1,09	1,3	1,3	1,1	1,4	111,8	0,06
Ireland	1,32	1,14	1,03	0,88	0,72	0,97	0,91	0,86	1,0	0,9	0,9	1,1	86,4	-0,46
Greece	0,75	0,66	0,65	0,73	b/d	0,62	0,67	0,70	0,7	0,7	0,7	0,7	60,3	-0,05
Spain	1,02	0,97	0,96	0,96	0,92	0,93	0,92	0,94	1,0	1,0	0,9	1,0	84,1	-0,08
France	1,24	1,24	1,25	1,25	1,22	1,23	1,23	1,21	1,2	1,2	1,2	1,2	108,9	-0,03
Croatia	b/d	b/d	b/d	b/d	0,81	0,86	0,87	0,86	0,9	0,9	0,9	0,9	75,1	b/d
Italy	0,79	0,81	0,80	0,76	0,73	0,75	0,77	0,78	0,8	0,8	0,8	0,8	68,3	-0,01
Cyprus	1,07	1,15	1,08	1,14	1,05	1,16	0,95	0,89	1,1	1,1	1,1	1,1	93,7	-0,18
Latvia	1,36	0,96	1,13	1,18	0,76	0,69	0,74	0,82	1,0	0,9	0,8	1,1	84,3	-0,54
Lithuania	1,40	4,58	1,33	1,18	0,82	0,75	0,79	0,80	1,5	1,0	0,8	1,3	128,6	-0,6
Luxembourg	0,45	b/d	0,51	0,51	0,48	0,46	0,41	0,45	0,5	0,5	0,5	0,5	41,2	0
Hungary	0,82	0,90	0,77	0,66	0,76	0,82	0,81	0,74	0,8	0,8	0,8	0,8	69,3	-0,08
Malta	1,66	1,75	1,67	1,55	1,37	1,21	1,28	1,33	1,5	1,5	1,3	1,7	130,5	-0,33
Netherlands	1,70	1,62	1,69	1,63	1,75	1,59	1,71	1,61	1,7	1,7	1,6	1,7	146,8	-0,09
Austria	1,89	1,80	1,79	1,80	1,78	1,71	1,70	1,56	1,8	1,8	1,7	1,8	154,9	-0,33
Poland	1,15	1,21	1,18	1,22	1,06	1,08	1,06	1,10	1,1	1,1	1,1	1,2	100,0	-0,05
Portugal	b/d	0,90	0,91	0,90	0,81	0,80	0,78	0,79	0,8	0,8	0,8	0,9	74,3	b/d
Romania	0,78	0,72	0,68	0,66	0,71	0,72	0,75	0,81	0,7	0,7	0,7	0,8	64,3	0,03
Slovenia	1,23	1,13	1,05	0,98	0,95	0,95	1,01	1,02	1,0	1,0	1,0	1,1	91,8	-0,21
Slovakia	b/d	0,97	0,97	1,39	0,83	0,79	0,76	b/d	1,0	0,9	0,8	1,0	84,0	b/d
Finland	b/d	2,01	2,00	1,89	1,83	1,66	1,54	1,51	1,8	1,8	1,6	1,9	156,9	b/d
Szweden	2,01	1,96	1,94	1,89	1,85	1,79	1,79	1,78	1,9	1,9	1,8	1,9	165,7	-0,23
UE-27	**1,23**	**1,24**	**1,24**	**1,18**	**b/d**	**1,18**	**1,19**	**1,19**	**1,2**	**1,2**	**1,2**	**1,2**	**106,6%**	**-0,04**

Legend: M – arithmetic mean, Me – median, Q_1 – first quartile, Q_3 – third quartile, b/d – no data.
Source: Own analysis based on Eurostat, https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4283841/default/table?lang=en; [access date 15.12.2022].

Appendix: Table 3. Human resources in science and technology aged 25-64 in the European Union 2012-2021 [% of total population].

Country / Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	M	Me	Q_1	Q_3	Structure [M Poland = 100%]	Changes to 2012 r. [p.p.]
Belgium	42,0	41,9	43,1	42,7	43,2	46,2	46,4	46,6	48,4	50,5	45,9	46,3	43,2	47,1	124,9	8,5
Bulgaria	27,6	29,2	30,7	31,2	31,4	31,8	32,3	32,3	33,4	33,6	32,1	32,1	31,4	32,6	87,4	6
Czech Republic	31,8	32,7	33,7	34,0	34,8	36,1	36,5	36,6	37,6	38,9	36,0	36,3	34,8	36,9	98,1	7,1
Denmark	46,6	47,0	47,6	48,2	49,2	50,5	51,4	52,1	52,7	54,2	50,7	51,0	49,2	52,3	138,2	7,6
Germany	41,1	41,6	41,7	42,3	43,0	43,5	44,1	45,2	45,6	45,7	43,9	43,8	43,0	45,3	119,5	4,6
Estonia	45,2	45,0	44,8	43,8	44,6	45,8	46,9	48,2	49,3	51,0	46,8	46,4	44,8	48,5	127,4	5,8
Ireland	44,6	46,1	46,7	47,6	48,4	49,9	50,6	51,6	53,8	56,2	50,6	50,3	48,4	52,2	137,8	11,6
Greece	29,2	30,2	30,8	31,6	33,0	33,9	34,4	34,7	35,7	37,5	34,0	34,2	33,0	35,0	92,4	8,3
Spain	35,8	36,7	37,7	38,3	38,9	39,7	40,5	41,9	42,8	43,9	40,5	40,1	38,9	42,1	110,2	8,1
France	41,1	42,0	42,3	43,2	43,7	44,1	45,5	46,5	48,0	48,3	45,2	44,8	43,7	46,9	123,1	7,2
Croatia	24,9	27,1	28,1	29,3	29,4	30,2	32,0	32,2	32,2	31,6	30,6	30,9	29,4	32,1	83,4	6,7
Italy	26,7	27,0	27,4	27,9	28,2	29,0	29,6	29,9	30,1	29,2	28,9	29,1	28,2	29,7	78,7	2,5
Cyprus	43,9	43,5	44,3	44,4	45,8	46,5	48,1	48,5	48,4	50,6	47,1	47,3	45,8	48,4	128,2	6,7
Latvia	35,3	36,6	36,4	38,0	38,9	40,1	40,0	42,0	44,0	44,9	40,5	40,1	38,9	42,5	110,4	9,6
Lithuania	38,9	40,3	41,4	43,2	44,1	44,5	45,8	47,2	48,0	49,4	45,5	45,2	44,1	47,4	123,8	10,5
Luxembourg	50,8	52,9	56,9	50,5	50,6	48,8	53,0	55,3	57,2	60,2	54,1	54,2	50,6	57,0	147,2	9,4
Hungary	29,3	30,0	30,8	31,6	31,4	32,0	33,0	34,1	35,6	37,6	33,3	32,5	31,6	34,5	90,6	8,3
Malta	26,8	28,7	30,0	31,2	31,9	34,2	37,8	40,2	40,8	42,2	36,0	36,0	31,9	40,4	98,1	15,4
Netherlands	45,5	46,0	46,1	47,0	47,9	48,7	50,3	52,3	54,4	56,7	50,4	49,5	47,9	52,8	137,3	11,2
Austria	34,9	36,3	41,5	42,0	42,7	43,8	44,2	45,1	45,8	46,0	43,9	44,0	42,7	45,3	119,5	11,1
Poland	30,5	31,7	32,9	34,0	35,1	36,5	37,5	38,4	39,3	40,1	36,7	37,0	35,1	38,6	100,0	9,6
Portugal	24,7	25,9	28,6	30,3	31,5	32,0	33,0	33,9	36,0	39,1	33,1	32,5	31,5	34,4	90,0	14,4
Romania	20,1	19,7	20,2	21,4	21,8	22,2	22,5	23,0	23,4	23,8	22,3	22,4	21,8	23,1	60,7	3,7
Slovenia	35,6	36,7	37,2	38,4	39,3	41,0	41,1	41,8	43,9	49,0	41,5	41,1	39,3	42,3	112,9	13,4
Slovakia	28,3	28,5	29,0	29,7	30,4	31,5	33,1	34,3	35,7	37,5	32,7	32,3	30,4	34,7	88,9	9,2
Finland	48,0	48,8	49,9	50,8	51,2	51,9	53,0	54,6	56,2	52,1	52,5	52,0	51,2	53,4	142,9	4,1
Szweden	48,7	49,9	51,3	52,3	54,0	54,9	56,3	56,9	57,7	58,9	55,3	55,6	54,0	57,1	150,5	10,2
UE-27	**35,2**	**35,9**	**36,7**	**37,4**	**38,1**	**38,9**	**39,8**	**40,7**	**41,7**	**42,3**	**39,5**	**39,4**	**38,1**	**41,0**	**107,4**	**7,1**

Legend: M – arithmetic mean, Me – median, Q_1 – first quartile, Q_3 – third quartile, b/d – no data.
Source: Own analysis based on Eurostat, https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4283841/default/table?lang=en; [access date 15.12.2022].

Appendix: Table 4. Expenditure in the business sector on research and development from 2012 to 2021 in the European Union [euro per capita].

Rok / Kraj	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	M	Me	Q_1	Q_3	Structure [M Poland = 100%]	The dynamics of change relative to 2012 r. [%]
Belgium	555,2	570,7	597,1	629,7	658,2	734,1	827,5	972,8	989,1	1 053,5	807,8	780,8	658,2	976,9	881,6	189,8
Bulgaria	21	22,4	30,8	44,3	38,4	38,5	43,2	49,2	50,8	52,3	43,4	43,8	38,5	49,6	47,4	249,0
Czech Rep.	144,7	151,9	162,3	167,5	171,7	204	233,9	251,7	244,3	279	214,3	219,0	171,7	246,2	233,9	192,8
Denmark	891,8	868,9	877,6	935,4	998,3	953,1	979,1	981,5	979	1 007,7	964,0	979,1	953,1	985,7	1052,1	113,0
Germany	669,6	665,2	705,7	750,7	764,5	833,6	870,9	913,4	854,1	904,2	824,6	843,9	764,5	879,2	900,0	135,0
Estonia	165,3	117,9	94,9	106,1	105,8	109,2	117,4	182,3	198,9	231,3	143,2	113,3	106,1	186,5	156,3	139,9
Ireland	427,5	438,6	454,3	477,4	485,1	579	575,1	664	683,1	716,7	579,3	577,1	485,1	668,8	632,3	167,6
Greece	41,4	44,4	46,2	51,7	68,7	92,3	97,7	100,5	107,3	116,6	85,1	95,0	68,7	102,2	92,9	281,6
Spain	151,5	147,8	145,9	149	153,4	166,1	181	186,2	185,2	204,6	171,4	173,6	153,4	185,5	187,1	135,0
France	460,2	466,3	470,5	476,5	485,1	494,2	507,6	524,3	522	536,3	502,1	500,9	485,1	522,6	548,0	116,5
Croatia	35,4	41,7	38,6	45,4	44,3	49,3	58,7	72,2	73,9	83,6	58,3	54,0	45,4	72,6	63,6	236,2
Italy	187	192,3	203,1	212	232,2	244,9	263,4	277,3	259,3	274,8	245,9	252,1	232,2	266,3	268,3	147,0
Cyprus	16,2	19,6	23,3	23	43,1	47,9	62,4	80,7	92,2	108,8	60,2	55,2	43,1	83,6	65,7	671,6
Latvia	16,2	19,5	28,9	18,9	13,7	19,2	23,9	26,7	33,8	40,2	25,7	25,3	19,2	30,1	28,0	248,1
Lithuania	26,7	28,5	39,5	36,5	39,7	49	63,5	75,2	95	109,2	63,5	56,3	39,7	80,2	69,2	409,0
Luxembourg	591,4	591,9	603,8	635	685,5	680,6	623,1	652,9	563,5	540,4	623,1	629,1	603,8	659,8	680,1	91,4
Hungary	83,1	99,2	103,5	112,6	103,4	124,8	158,6	165,9	171,9	196,3	142,1	141,7	112,6	167,4	155,1	236,2
Malta	81,9	72,3	77,9	83,5	80,7	93,6	98,8	100,5	106,3	116,1	94,7	96,2	83,5	102,0	103,3	141,8
Netherlands	423	554,2	561,2	563	589,4	624,5	640,1	685,4	707,4	745,7	639,6	632,3	589,4	690,9	698,0	176,3
Austria	777,9	802	860,9	873,4	899,3	899,2	943,4	987,6	953,1	1 008,3	928,2	921,4	899,2	961,7	1013,0	129,6
Poland	33,5	39,4	47,3	52,9	71,1	82,1	104,7	116,6	120,7	137,6	91,6	93,4	71,1	117,6	100,0	410,7
Portugal	109,4	102,3	99,4	99,9	111,8	126,4	138,4	152,8	179,1	205	139,1	132,4	111,8	159,4	151,8	187,4
Romania	12,5	8,5	12	17,3	22,9	27,3	31,1	31,8	31,3	35,9	26,2	29,2	22,9	31,4	28,6	287,2
Slovenia	342,1	347,5	334,1	315,4	297,8	290,4	320,5	351,4	352,4	388,8	331,4	327,3	315,4	351,7	361,6	113,7
Slovakia	44,8	52,2	45,5	47,8	59,5	74,6	74,6	78,1	83,1	94,3	69,7	74,6	59,5	79,4	76,1	210,5
Finland	869,2	848,1	808,9	739,7	711	732	766,7	798,8	840,6	931,1	791,1	782,8	739,7	816,8	863,4	107,1
Szweden	993	1 039,4	946,2	1 048,3	1 069,5	1 151,9	1 095,9	1 132,2	1 174,8	1 249	1 108,5	1 114,1	1069,5	1157,6	1209,8	125,8
UE-27	**341,1**	**349,5**	**360,4**	**377**	**391,4**	**419**	**440,6**	**465,7**	**455,8**	**484,4**	**424,3**	**429,8**	**391,4**	**458,3**	**463,1**	**142,0**

Legend: M – arithmetic mean, Me – median, Q_1 – first quartile, Q_3 – third quartile, b/d – no data.
Source: Own analysis based on Eurostat, https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4283841/default/table?lang=en; [access date 15.12.2022].

Appendix: Table 5. Applications to the EPO between 2012 and 2021 among European Union countries [number of patent applications].

Year / Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	M	Me	Q_1	Q_3	Structure [MPoland = 100%]	The dynamics of change relative to 2012 r. [%]
Belgium	1 874	1 995	1 964	1 992	2 046	2 213	2 281	2 341	2 306	2 317	2 182,5	2 247,0	2046,0	2308,8	443,7	123,6
Bulgaria	1 892	1 885	1 927	2 041	2 196	2 155	2 348	2 423	2 406	2 485	2 247,6	2 272,0	2155,0	2410,3	457,0	131,3
Czech Republic	13	22	34	33	20	32	31	34	54	40	34,8	33,5	32,0	35,5	7,1	307,7
Denmark	19	10	12	9	14	10	14	19	23	27	16,0	14,0	12,0	20,0	3,3	142,1
Germany	53	45	44	37	37	49	49	47	65	44	46,5	45,5	44,0	49,0	9,5	83,0
Estonia	139	149	167	213	190	205	248	198	206	203	203,8	204,0	198,0	207,8	41,4	146,0
Ireland	1 605	1 929	1 983	1 930	1 869	2 114	2 385	2 404	2 420	2 642	2 218,4	2 249,5	1983,0	2408,0	451,0	164,6
Greece	42	41	38	32	44	54	47	49	57	69	48,8	48,0	44,0	54,8	9,9	164,3
Spain	1 854	1 895	2 182	2 000	1 820	1 818	1 728	1 703	1 899	2 111	1 907,6	1 859,5	1818,0	2027,8	387,8	113,9
France	9 918	9 754	10 614	10 781	10 504	10 559	10 468	10 163	10 614	10 537	10 530,0	10 548,0	10504,0	10614,0	2140,8	106,2
Croatia	83	66	95	86	74	100	120	139	135	198	118,4	110,0	95,0	136,0	24,1	238,6
Italy	1 546	1 504	1 471	1 527	1 560	1 676	1 781	1 887	1 794	1 954	1 706,3	1 728,5	1560,0	1817,3	346,9	126,4
Cyprus	5 063	5 826	6 874	7 100	6 857	7 043	7 142	6 954	6 386	6 581	6 867,1	6 914,0	6857,0	7057,3	1396,1	130,0
Latvia	593	548	622	582	682	593	826	878	980	956	764,9	754,0	622,0	897,5	155,5	161,2
Lithuania	19	22	24	39	27	24	37	29	50	73	37,9	33,0	27,0	41,8	7,7	384,2
Luxembourg	402	398	454	404	564	581	431	427	402	430	461,6	430,5	427,0	481,5	93,9	107,0
Hungary	25	80	8	29	12	15	13	22	30	22	18,9	18,5	13,0	23,8	3,8	88,0
Malta	23	43	62	85	90	107	51	56	63	51	70,6	62,5	56,0	86,3	14,4	221,7
Netherlands	27 276	26 645	25 633	24 820	25 012	25 490	26 663	26 805	25 882	25 969	25 784,3	25 757,5	25490,0	26142,5	5242,0	95,2
Austria	385	371	482	568	411	469	519	469	478	539	491,9	480,0	469,0	524,0	100,0	140,0
Poland	75	94	113	137	158	149	221	272	251	286	198,4	189,5	149,0	256,3	40,3	381,3
Portugal	35	30	28	33	30	50	50	40	55	30	39,5	36,5	30,0	50,0	8,0	85,7
Romania	35	29	26	48	42	41	51	42	54	42	43,3	42,0	42,0	48,8	8,8	120,0
Slovenia	108	135	125	118	114	96	100	121	165	116	119,4	117,0	114,0	122,0	24,3	107,4
Slovakia	3 530	3 668	3 873	3 839	3 555	3 728	4 055	4 381	4 422	4 954	4 100,9	3 964,0	3839,0	4391,3	833,7	140,3
Finland	105	103	114	99	110	94	118	100	109	118	107,8	109,5	100,0	115,0	21,9	112,4
Szweden	3 753	3 704	3 649	3 979	4 172	4 352	4 404	4 456	4 619	4 919	4 318,8	4 378,0	4172,0	4496,8	878,0	131,1
UE-27	**60 465**	**60 991**	**62 618**	**62 561**	**62 210**	**63 817**	**66 181**	**66 459**	**65 925**	**67 713**	**64 685,5**	**64 871,0**	**62618,0**	**66250,5**	**13150,8**	**112,0**

Legend: M – arithmetic mean, Me – median, Q_1 – first quartile, Q_3 – third quartile, b/d – no data.
Source: Own analysis based on Eurostat, https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_PERP04__custom_4283841/default/table?lang=en; [access date 15.12.2022