AGORA International Journal of Economical Sciences, http://univagora.ro/jour/index.php/aijes
ISSN 2067-3310, E-ISSN 2067-7669
Vol. 19, No. 2 (2025), pp. 302-314

INTERNATIONAL TECHNOLOGICAL COMPETITIVENESS OF POLAND AFTER TWO DECADES OF EU MEMBERSHIP

M. MOSTOWSKA

Martyna Mostowska
Radom Academy of Economics, Poland
E-mail: mmostowska@ahns.pl

Abstract: *The aim of the article is to assess the changes in Poland's technological development and international competitive position in the field of technology in the context of integration with the European Union. The analyzed period — 1995–2023 — was chosen in order to answer the following research questions: (1) what changes have occurred in the area of the country's technological competitiveness? and (2) what government policies support the development of innovation? The study applies a mixed-method approach, combining quantitative analysis of technological indicators with a qualitative assessment of political strategies and innovation support programs. The results indicate an improvement in Poland's technological capabilities, particularly in the IT sector and high-tech industries, supported by EU funds and international cooperation. At the same time, challenges such as insufficient commercialization of innovations and a focus on medium-tech sectors limit the full use of Poland's potential. Therefore, it remains necessary to strengthen the national innovation ecosystem so that Poland can achieve a lasting competitive advantage in the global knowledge-based economy.*
Keywords: *competitveness, technology, international trade, Poland, European Union*

1. Introduction

The significance of technology for the modern economy — particularly its impact on broadly understood economic growth and development — continues to be a subject of academic discussion. A pioneering figure who introduced the concept (and term) of innovation — understood as the continual emergence of new technological solutions — was J. Schumpeter, whose considerations, however, primarily focused on individual entrepreneurship (Śledzik, 2013, p. 89). Nevertheless, his ideas can be regarded as the foundation for further studies by other scholars, including those whose research interests encompassed such issues as the determinants of economic growth and development, as well as the international competitiveness of nations.

The outcome of M. Porter's reflections was the identification of a new phase of economic development based on innovation, in which knowledge serves as a key determinant of economic growth. Technology influences the economy in two ways — through innovation, meaning the implementation of new inventions, and imitation, based on the transfer of technology from more developed countries as a cheaper alternative to its independent, domestic creation (Huang & Hu, 2024, p. 110–111). In many other models of economic growth, the research and development (R&D) sector is also assigned significant importance — labor productivity and the efficiency of production factors are positively correlated with a country's resources devoted to R&D activities. Furthermore, the literature provides numerous studies on growth models demonstrating a causal relationship between scientific development and economic growth (cf. Romer, 1990; Grossman, Helpman, 1991; Aghion, Howitt, 1992). Their key assumption is the diffusion of knowledge, which, through externalities, can offset the high costs of research. In addition to domestic knowledge diffusion, there also exists international technology transfer, stimulated by research expenditures in countries that are major trading partners (cf. Coe, Helpman, 1995; Engelbrecht, 1997; Frantzen, 2000).

The issue of a country's economic competitiveness is closely linked to economic growth, development, and their determinants. According to the aforementioned M. Porter (2001, p. 196–197),

national competitiveness is the effective utilization of resources in production, measured by productivity. Similarly, P. Krugman argues that "the main factor of competitiveness is the growth of productivity of production factors and technological progress" (Krugman, 1994, p. 31), while emphasizing that competitiveness is also related to export efficiency and a high standard of living (Siudek, Zawojska, 2014, p. 95). W. Bieńkowski (1995, p. 22–23) agrees with these views, identifying among the determinants of international economic competitiveness the production resources — namely, natural resources, labor, capital, and technology — as well as the efficiency of their use in production processes. Moreover, the author stresses the importance of international trade cooperation in shaping a country's global competitiveness. As he notes, "a measure of the growth of competitive ability is (…) the preservation by a given economy of its capacity for long-term profitable development (…), resulting in such an economic structure — and consequently an export structure — that corresponds to long-term changes in the structure of global demand" (Bieńkowski, 1995, p. 34).

Trade partnerships — both at the level of countries and enterprises — can therefore also be regarded as a factor influencing economic growth and development, and consequently, competitiveness. More broadly, however, economic integration processes as a whole may likewise be considered a determinant of countries' international competitiveness, including in the technological sphere. The relationship between these two variables remains the subject of academic research (Petrović, Antevski, 2008; Bieńkowski, Bukowski, Olszewska, 2012), the results of which confirm their existence, emphasizing in particular the benefits for technology-importing countries — whether in the form of high-tech products or foreign direct investments by transnational corporations originating from countries considered global leaders in innovation (Mostowska, 2024, p. 330–332).

In contemporary approaches to international competitiveness, the emphasis is placed on the economy's ability to attract investment, foster innovation, and adapt to global changes. One of the determinants of a country's competitiveness growth is technological development, which enhances the efficiency of resource utilization. Equally important are the processes of economic integration between countries, which facilitate knowledge transfer, access to larger markets, R&D collaboration, and inflows of investment that stimulate innovation. These interdependencies provide a rationale for examining the impact of EU membership on Poland's international competitive position in the technological sphere, making such an analysis both justified and necessary.

2. Research Methodology

The main aim of the study is to characterize the changes in Poland's international technological competitiveness between 1995 and 2023. Within this framework, three specific objectives were also formulated: to describe the changes in the areas of: trade in technology-intensive goods, domestic research and development activities, and policies supporting the country's technological development.

The statistical data used in the study were drawn from publicly available international databases, namely UNCTAD Stat and EUROSTAT. Additionally, information from national sources (e.g., the Ministry of Development and Technology, the Polish Agency for Enterprise Development) and EU websites (e.g., Eur-Lex) was also utilized.

The study was conducted using descriptive statistical tools (structure and dynamics indicators) as well as a synthetic competitiveness measure — the revealed comparative advantage index.

3. Results

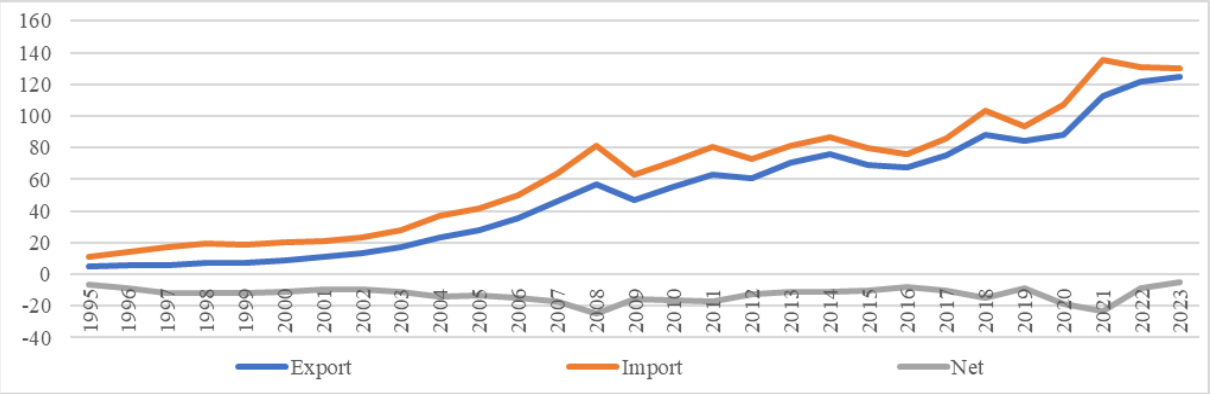
3.1. Trade in Technologically Intensive Goods

In the pre-accession decade (i.e., 1995–2004), the volume of Poland's trade in technology-intensive goods increased steadily (with exports rising nearly fivefold and imports more than threefold). It should also be noted that this upward trend was observed slightly longer, over the first fourteen years of the analysis (i.e., 1995–2008).

The trend reversal — not only in Poland and not only in the area of high-tech goods — occurred as a result of the global economic downturn that began in the United States. In subsequent years, both

increases and decreases in the volume of this type of trade were observed in Poland; however, throughout the entire analyzed period, Poland remained a net importer of technology-intensive products (Figure 1).

Figure 1. *Volume of Poland's Trade in Technology-Intensive Goods in 1995–2023 (billion USD)*

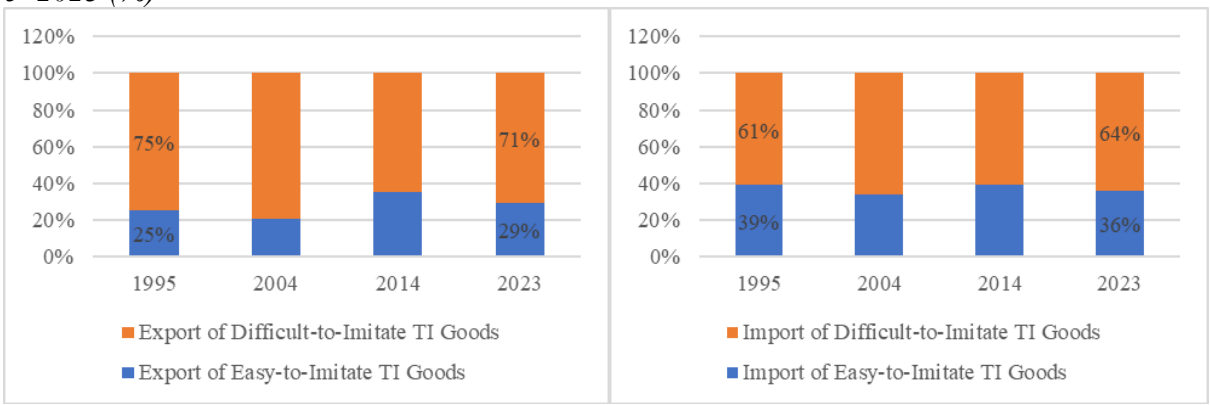


Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

The negative trade balance in the initial years of the analysis steadily deepened (1995–2008), but in the following years showed a reverse trend — which, combined with trade volume, should be interpreted as an improvement in the country's technological competitiveness. It is, however, worth noting that the average growth rate of both exports and imports of technology-intensive goods was higher in the pre-accession period — in 1995–2004 it amounted to approximately 17%, while in 2005–2023 it was around 10%. There were certainly many reasons for this pattern, but the global economic downturn mentioned earlier should be highlighted as a major factor.

Valuable insights on this topic can also be provided by analyzing the structure of Poland's trade in technology-intensive goods (1), the share of this type of trade in the country's overall trade and in EU trade (2), as well as the development of the revealed comparative advantage index (3), which in the literature is considered a synthetic measure of a country's competitiveness (cf. Misala, 2007; Pilarska, 2017). In the first case, it is reasonable to refer to M. Weresa's classification of technology-intensive goods into easily and difficult-to-imitate products (cf. Weresa, 2007). The first group includes chemical products, pharmaceuticals, and IT and telecommunications equipment, while the second comprises metalworking machinery, specialized equipment, and precision instruments. The commodity structure of Poland's trade in technology-intensive goods is illustrated below (Figure 2).

Figure 2. *Commodity Structure of Poland's Trade in Technology-Intensive Goods in Selected Years of 1995–2023 (%)*

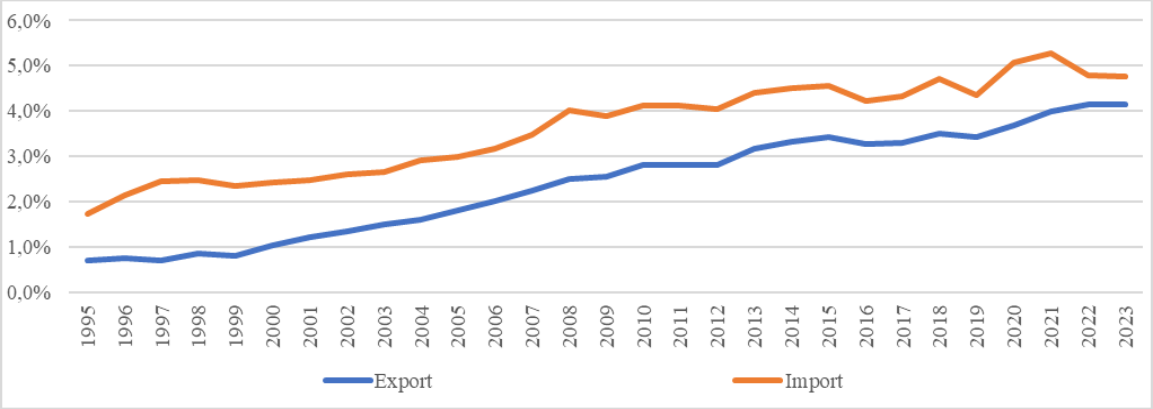


Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

Based on the presented data, it can be concluded that no significant changes occurred in the commodity structure of Poland's trade in technology-intensive goods that could be interpreted as a sign of increased international economic competitiveness. In exports, the share of difficult-to-imitate goods decreased slightly, while in imports, the share of easily imitable goods declined. It is worth noting — and can be considered an indication of the country's growing technological competitiveness — that in the final year of the analysis, Poland recorded a positive trade balance in difficult-to-imitate technology-intensive goods (amounting to USD 4.9 billion), and products from this group accounted for over 25% of the country's total exports. This was likely driven by exports of goods in the "Electrical apparatus, machinery, and equipment" category (41% of technology-intensive exports in 2023, compared to 27% in 1995) and "General industrial machinery and machine parts" (19% in 2023 versus 12% in 1995).

During the analyzed period, the significance of technology-intensive goods in Poland's overall foreign trade also changed. Their share in exports increased significantly (from 22% in 1995 to 35% in 2023), while in imports it decreased slightly (from 39% to 38%, respectively). Moreover, when considering Poland's technological competitiveness as an EU member state, it is also reasonable to highlight data illustrating the importance of the country's trade in technology-intensive goods relative to such trade across the entire Union (Figure 3).

Figure 3. *Share of Poland's Trade in Technology-Intensive Goods in the EU's Technology-Intensive Trade, 1995–2023 (%)*



Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

Consistent with the data presented so far, it should be noted that the share of imports (4,8% in 2023) of technology-intensive goods in the overall EU trade of this type was higher than that of exports (4,2%). However, a nearly uninterrupted increase in this share is clearly visible — almost a threefold rise in imports (from 1,7% in the first year of the analysis) and more than a sixfold increase in exports (from 0,7% in 1995).

Table 1. *Revealed Comparative Advantage (RCA) Indicators of Poland's International Trade in Easy to Imitate Technology-Intensive Goods in Selected Years of 1995–2023**

Specification **	1995	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023
51	-0,2	-0,1	-0,1	-0,4	-0,4	-0,6	-0,4	-0,7	-0,4	-0,7	-1,0	-1,0	-0,7	-0,8	-0,9
52	0,8	0,7	0,3	0,3	0,1	0,0	-0,1	-0,3	-0,2	-0,2	-0,4	-0,3	-0,3	-0,9	-1,2
54	-1,2	-1,0	-1,8	-2,0	-2,1	-1,6	-1,3	-1,0	-0,9	-0,6	-0,6	-0,4	-0,6	-0,8	-0,7
58	-2,0	-1,4	-1,4	-0,9	-0,8	-0,6	-0,3	-0,3	-0,3	-0,2	-0,2	-0,1	0,0	0,0	0,0
59	-1,6	-1,5	-1,5	-1,2	-1,4	-1,2	-1,2	-1,2	-0,8	-0,7	-0,6	-0,4	-0,2	-0,1	-0,2
75	-3,1	-2,7	-2,4	-2,5	-2,4	-2,1	-1,6	-0,2	-0,2	-0,5	-0,3	-0,4	-0,2	-0,4	-0,3
76	-1,2	-0,4	-0,4	-0,2	0,0	-0,2	0,0	0,3	0,3	0,1	0,1	0,2	0,1	0,2	0,4

*Calculations performed according to the formula: $RCA_i = \ln(\frac{x_i \div m_i}{X \div M})$, where: x_i – value of exports of the country and within the product group, m_i – value of imports of the country and within the product group, X – total value of the country's exports, M – total value of the country's imports; the indicator is calculated using the 2-digit SITC classification, and its value oscillates between +∞ and -∞, with positive values indicating a relative advantage.
** Legend: 51 – organic chemicals, 52 – inorganic chemicals, 54 – medicinal and pharmaceutical products, 58 – processed plastics, 59 – chemical products and materials, 75 – office machines and computer equipment, 76 – telecommunications equipment and devices. Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

Changes in Poland's international technological competitiveness in the technological sphere can also be measured using a synthetic indicator, the revealed comparative advantage (RCA) index — used to assess a country's trade specialization in selected groups of goods or services relative to other countries. It is widely applied in international analyses, particularly in studies on competitiveness and the structure of foreign trade. Its values for Poland's trade in technology-intensive goods in selected years of the analyzed period are illustrated below (Table 1).

In the area of trade in easily imitable technology-intensive goods, Poland initially held a comparative advantage only in organic chemicals, which it permanently lost in 2007. However, it gained an advantage in the trade of telecommunications equipment and devices and effectively leveraged this advantage — exports of products from this group accounted for over 8% of the country's total exports in 2023. The situation is considerably more favorable in terms of competitiveness in difficult-to-imitate technology-intensive goods.

Table 2. *Revealed Comparative Advantage (RCA) Indicators of Poland's International Trade in Difficult to Imitate Technology-Intensive Goods in Selected Years of 1995–2023**

Specification **	1995	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023
57	-1,2	-1,2	-1,3	-1,2	-1,4	-1,3	-0,9	-1,0	-0,9	-0,9	-0,9	-1,0	-1,1	-1,2	-1,2
71	-0,2	-0,3	-0,3	0,7	0,8	0,6	0,7	0,4	0,4	0,3	0,2	0,4	0,3	0,3	0,2
72	-0,8	-0,8	-0,7	-0,7	-0,7	-0,5	-0,6	-0,6	-0,5	-0,3	-0,4	-0,3	-0,4	-0,4	-0,3
73	-0,9	-1,0	-0,9	-0,5	-1,0	-0,8	-0,7	-0,9	-0,5	-0,6	-0,8	-0,8	-0,8	-0,8	-0,6
74	-1,1	-0,9	-0,8	-0,7	-0,6	-0,5	-0,3	-0,4	-0,3	-0,2	-0,3	-0,1	-0,1	-0,2	-0,1
77	-0,2	-0,1	0,0	0,0	0,2	0,2	0,4	0,1	0,2	0,2	0,1	0,1	0,1	0,1	0,3
79	2,9	0,4	2,1	1,1	0,6	0,6	0,8	0,5	0,5	0,3	0,2	0,3	0,1	0,7	0,1
87	-1,3	-1,2	-1,1	-1,1	-0,5	-0,5	-1,0	-1,1	-1,0	-0,5	-0,4	-0,2	-0,2	-0,2	-0,2
88	-2,5	-1,6	-2,1	-2,4	-2,0	-1,3	-1,4	-1,3	-1,0	-1,0	-0,8	-0,6	-0,6	-0,5	-0,6

*Calculations performed according to the formula: as in the previous table.
** Legend: 57 – unprocessed plastics, 71 – electrical machinery and equipment, 72 – specialist equipment for industry, 73 – metalworking machinery and equipment, 74 – general industrial equipment and machine parts, 77 – electrical machinery and equipment, 79 – other transport equipment, 87 – control equipment and instruments, 88 – photographic equipment, optical products, clocks. Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

In the base year of the analysis, Poland held a competitive advantage only in the trade of transport equipment, whereas nearly three decades later, it had also gained an advantage in two additional categories of internationally traded goods: electrical apparatus, machinery, and equipment. Similar to easily imitable technology-intensive goods, the export of these products accounted for the largest share of the country's total exports, reaching 45% in 2023.

3.2. Research and Development (R&D) sector

An improvement in Poland's international technological competitiveness over the period 1995–2023 can also be observed by analyzing data on the country's R&D sector (Table 3). Expenditures on the R&D sector steadily increased over the analyzed period, both in absolute and relative terms. In 1995, nine years before Poland's accession to the EU, national spending on research and development amounted to EUR 672 million, representing only 0,6% of GDP and approximately EUR 17 per capita. Nearly three decades later, in 2023, these expenditures accounted for just over 1,5% of Poland's GDP, totaling EUR 11,7 billion, or nearly EUR 320 per capita. This represents more than a twofold increase in such investments (considering GDP dynamics), which is undoubtedly a positive indicator regarding changes in the country's technological competitiveness.

Table 3. *Size and Structure of Poland's Research and Development (R&D) Expenditures in Selected Years of 1995–2023*

Specification	1995	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023
R&D expenditure as:															
% GDP	0,62	0,64	0,68	0,62	0,54	0,56	0,56	0,66	0,75	0,88	1,00	1,03	1,31	1,44	1,56
euro per capita	17	23	28	35	27	36	46	55	75	90	114	127	186	223	318
Financing structure (%):															
Business Sector	39	39	41	36	27	32	30	28	30	44	47	64	63	63	65
Government Sector	35	32	31	31	41	36	35	34	35	27	24	2	1	2	2
Higher Education Sector	26	29	28	33	32	32	34	37	35	29	29	33	36	35	33
Non-Profit Sector	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: own study based on: EUROSTAT Database, https://ec.europa.eu/eurostat/web/main/data/database [accessed 13/01/2025].

Positive developments were also observed in the sectoral structure of R&D financing — over the analyzed period, the share of funding for the business sector and higher education significantly increased, relative to the government sector. The growing participation of enterprises in this structure can be interpreted as an increase in the private sector's autonomy, the development of the innovation ecosystem, and, consequently, higher efficiency of R&D spending (driven by private entities' focus on effectiveness), as well as reduced dependence of the private sector on public funds.

Similar changes, corresponding to those previously observed, were noted in employment within Poland's R&D sector (Table 4).

Table 4. *Size and Structure of Employment (by Occupation) in Poland's Research and Development (R&D) Sector in Selected Years of 1995–2022**

Specification	1995	1999	2003	2007	2011	2015	2019	2022
Absolute size of employment in the R&D sector (thousands of people)	120,0	126,0	126,2	121,6	134,6	157,9	271,0	321,4
Relative size of employment in the R&D sector (in relation to all economically active people, %)	n/a.	0,87	0,95	0,81	0,91	1,02	1,65	n/a.
Employment structure by type of position held (%):								
Researchers	62	69	75	80	75	75	72	70
Technicians and equivalent Staff	21	17	13	11	16	15	18	21
Other	16	14	12	9	9	10	10	9
Employment structure by economic sector (%):								

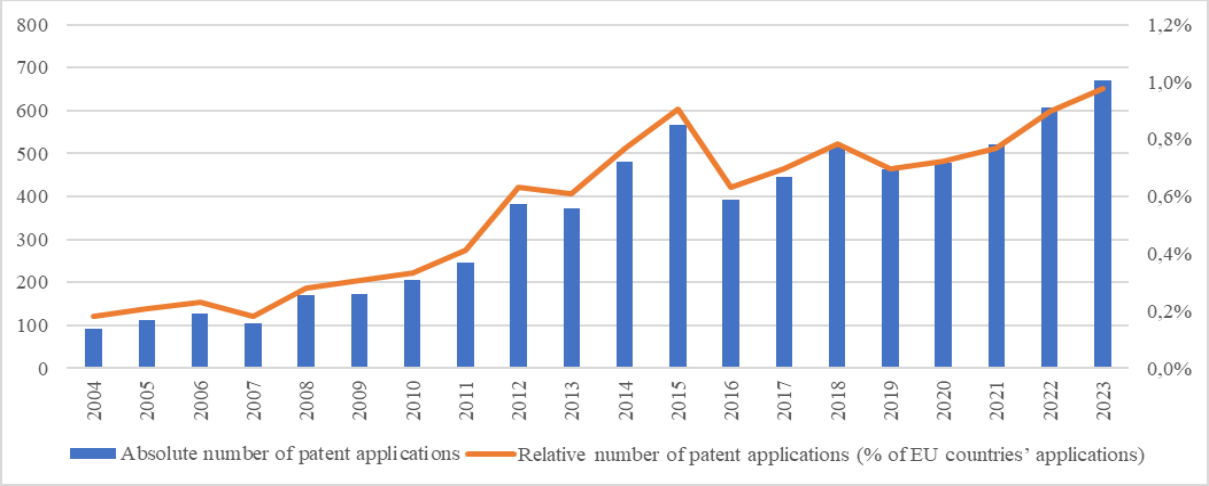
Business Sector	26	21	12	15	20	31	45	53
Government Sector	20	18	20	19	20	17	2	2
Higher Education Sector	54	61	68	66	60	52	52	44
Non-Profit Sector	0	0	0	0	0	0	1	0

*no data for 2023.
Source: own study based on: EUROSTAT Database, https://ec.europa.eu/eurostat/web/main/data/database [accessed 13.01.2025].

Between 1995 and 2022, Poland's R&D sector experienced a systematic increase in employment, nearly tripling in absolute terms and almost doubling in relative terms. Throughout the analyzed period, the employment structure by occupation was dominated by researchers (70% of the total in 2023), followed by technicians (21%). Positive changes, mirroring those observed in R&D sector financing, were also evident in the sectoral employment structure: employment in the enterprise sector increased by 27 percentage points to 50%, while government sector employment decreased by 18 percentage points to just under 2%. Additionally, the higher education sector's share of R&D specialists remained relatively stable, declining by 10 percentage points to 44% in 2023.

Another measure of a country's technological competitiveness is the ability of its citizens to generate knowledge, which can be tangibly reflected in patents. In this area of R&D activity, Poland also experienced positive developments during the analyzed period (Figure 4).

Figure 4. *Patent applications in Poland in the period 2004–2023* (in absolute and relative terms)*



* Data unavailable for 1995–2003.
Source: own study based on: UNCTADstat, https://unctadstat.unctad.org/datacentre/ [accessed 12.01.2025].

The absolute number of patent applications in Poland during the analyzed period increased more than sevenfold (from 93 applications in 2004 to 671 applications in 2023). This growth was also reflected in relative terms, i.e., Poland's share of total patent applications in EU countries, which rose by 0.8 percentage points. However, despite this increase, the share in 2023 remained just under 1%. It is worth supplementing this description with additional information of significant relevance for assessing changes in the area of Poland's international technological competitiveness (Polish Patent Office, 2024):

- Poland ranks seventh among countries affiliated with the European Patent Office (EPO) in terms of the growth rate of patent applications and tenth in the world;
- in 2023, the majority of patent applications from Poland pertained to medical technologies, pharmaceuticals, and civil engineering;
- among the applicants to the EPO, Polish universities and research institutes demonstrate the highest level of activity.

3.3. Policies Supporting Technological Competitiveness

Referring to the last area of Poland's international technological competitiveness assessed in this analysis – supporting policies – it seems appropriate to point to both holistic solutions (1) and those specifically aimed at the country's technological development (2). In the first case, the primary example is the Strategy for Responsible Development, which serves as the main document defining Poland's goals and directions in social, economic, and regional development, with the overarching objective of creating conditions for increasing citizens' incomes while simultaneously enhancing social, economic, and territorial cohesion (Government of the Republic of Poland 1, 2024). Additionally, it is worth mentioning the Productivity Strategy 2030, an update and expansion of earlier strategies, focused on increasing the efficiency and innovativeness of the Polish economy through investments in modern technologies, human capital development, and support for entrepreneurship; the National Smart Specializations, which define priority R&D and innovation areas where Poland has or can achieve competitive advantages, aiming to concentrate resources and actions on key sectors to support the effective use of funds and foster innovation (Government of the Republic of Poland 2, 2024); and the State Science Policy, which sets directions and priorities for the development of science and research in Poland, including knowledge and technology transfer between academia and industry, as well as striving for technological independence through the creation of Polish "know-how" (Government of the Republic of Poland 3, 2024).

In the second case, i.e., with direct reference to the development of innovation in Poland (and consequently its competitive position in this area), it is important to mention certain initiatives implemented both at the national and EU levels. Regarding government (domestic) policies, the key examples are the Program of the Minister of Development and Technology for the Promotion and Development of Innovation and the SMART Pathway. The first program focuses on supporting innovation and promoting new ideas, technologies, and services that address key social, environmental, and economic needs in Poland (Government of the Republic of Poland 4, 2024). The second initiative provides significant financial support for consortia investing in innovative and development projects – entrepreneurs can receive funding of up to PLN 150 million for the implementation of groundbreaking projects (Government of the Republic of Poland 5, 2024).

In the area of EU policies, it is worth mentioning the European Funds for Research, Development, and Innovation, which have played a key role in financing national R&D activities since Poland joined the EU – during 2004–2021, R&D expenditures in Poland increased by over 624%, reaching 1,44% of GDP (Polish Agency for Enterprise Development 1, 2025). Another example is the European Funds for the Modern Economy Program, which introduced new forms of support for business innovation, with a budget of up to PLN 4 billion allocated to R&D and production activities (Polish Agency for Enterprise Development 2, 2025). Thanks to the synergy of these initiatives, Poland has the opportunity to achieve dynamic growth in its innovation capacity and, consequently, its international technological competitiveness.

4. Discussion

The period 1990–2004 was a time of intensive systemic transformations and dynamic economic growth for the Polish economy. The foundation of these changes was a set of groundbreaking institutional reforms prepared in the autumn of 1989, aimed at eliminating the negative effects of a centrally planned economy. An additional confirmation of the country's credibility as a candidate for a free-market, competitive economy was the signing, on 19 September 1989, of an agreement with the European Communities regulating trade and economic relations between the parties. This marked the beginning of a process—lasting just under 15 years—that ultimately led to Poland's integration into European structures. This process strongly stimulated changes in the structure of the Polish economy and, consequently, its international competitiveness.

The category of a country's international economic competitiveness is a complex and multidimensional concept, lacking a single, universally accepted definition. The reasons for this are

certainly numerous; however, among the most frequently cited in the literature (cf. Wziątek-Kubiak, 2004; Żmuda, Molendowski, 2016; Pilarska, 2017) are primarily the following:

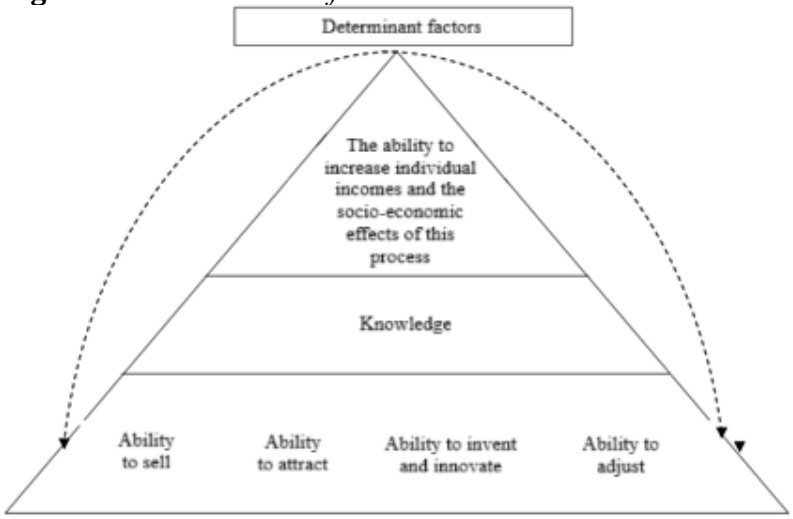
- the aforementioned multiplicity of competitiveness dimensions – encompassing economic aspects (e.g., productivity, exports), social aspects (e.g., standard of living, human capital), and technological aspects (e.g., innovation, capacity to adapt to changes);
- the diversity of theoretical approaches – researchers emphasize different elements of competitiveness, such as the ability to generate economic growth, investment attractiveness, or institutional efficiency;
- the unique characteristics of national economies – distinctive features arising from natural resources, industrial structure, technological level, or economic policy, which make it difficult to apply a single measure across all countries;
- difficulties in obtaining and interpreting relevant statistical data – measuring competitiveness involves numerous indicators, such as GDP per capita, R&D expenditures, trade balance, or level of innovation, whose precise measurement can be challenging due to methodological reasons.

Such a situation implies both the multiplicity of ways to measure a country's international competitiveness and the difficulty of formulating a single, synthetic indicator that would significantly facilitate comparisons between selected countries (cf. Mostowska, 2024, p. 68). However, it is possible to measure certain constituent elements of this competitiveness, and the basis for both identifying and applying specific measures lies in the model-based solutions systematized in the literature.

Taking into account the specificity of the Polish economy (especially during the period analyzed in this study, covering the years of economic transformation), it seems appropriate to refer to the model proposed by K. Akamatsu, which relates the economic development of a country (and thus its competitiveness) to its "openness" in foreign economic relations. According to the author, a key factor supporting economic growth is the transfer of technology. This process primarily occurs through the activities of transnational corporations, which introduce technologies via foreign investments, as well as through the export of technologically advanced products. The diffusion of technology improves the efficiency of other production resources, enabling higher levels of economic development and increasing national competitiveness. However, this model requires certain conditions to be met. Critical importance is placed on economic policies based on the liberalization of international trade, openness to foreign capital inflows, and support for exports (cf. Bożyk, Misala, Puławski, 2002). An extension of these considerations was presented by T. Ozawa, who developed the theory of dynamic comparative advantages based on M. Porter's model, describing four stages of economic development for countries. In the initial stage, based on production factors, political stability, market liberalization, and attraction of foreign investments are crucial. Economies at this stage focus on simple products, relying on technology imported from more developed countries, and their enterprises compete mainly on price and basic production processes. The next, investment-driven phase requires modernization of infrastructure and regulations to support greater integration with global markets. At this stage, firms improve production efficiency, enhance imported technologies, and participate in international value chains, although the economy remains vulnerable to crises arising from dependence on foreign capital. The transition to the innovation stage requires an active government role, support for research and development, higher education, and modern capital markets. Firms become more flexible and networked, investing in employee skill development and creating industrial clusters that promote competitiveness and globally significant innovation. However, as with many economies, challenges arise during transitions between stages, often leading to stagnation. The key challenge is understanding the need for adjustments in market organization, government policies, and business practices, which often constitutes a barrier to further economic growth (Ozawa, 1992, p. 27-54). These patterns could be observed (and can still be observed) in the case of the Polish economy..

Determinants of economic growth and development, such as technological progress, human capital, investment, and knowledge diffusion, directly influence a country's ability to compete in international markets and, consequently, to build its international competitiveness. The concept of "capability" appears crucial in this context, especially when considering one of the frequently presented models of determinants of national international competitiveness along with their indicators (Figure 5).

Figure 5. *Determinants of a nation's international economic competitiveness*



Source: Misala, 2014, p. 8.

One of the areas determining a country's international competitiveness is its capacity for invention and innovation, which shapes the country's competitive position in the technological sphere. Key indicators include the analysis of competitive standing in trade of technology-intensive goods, expenditures on science and research (both in absolute terms and relative to GDP) and their structure, the size and structure of employment in the research and development sector, as well as absolute and relative numbers of patent applications along with their structure. Analyzing changes in these indicators over time can provide insights into the direction of a country's technological international competitiveness.

The results of the analysis conducted in this study provide grounds for concluding an improvement in Poland's international technological competitiveness, which is reflected mainly through:

- a systematic increase in the volume of trade in technology-intensive goods, as well as their share in the overall structure of the country's exports (25% in 2023);
- the dominance of hard-to-imitate goods in the composition of technology-intensive trade throughout the analyzed period, and in the last year of the analysis – recording a positive trade balance (USD 4,9 billion);
- a systematic increase in the share of Poland's trade in technology-intensive goods within the EU's corresponding trade (4,8% for imports and 4,2% for exports in 2023);
- an increase in the number of categories of technology-intensive goods in which the country holds a revealed comparative advantage (two additional categories compared to 1995);
- a systematic increase in expenditures on research and development activities (from 0,6% to 1,5% of GDP) and changes in their structure (an increase in the share of enterprises and higher education at the expense of the government sector, indicating the development of the innovation ecosystem, greater efficiency of spending, and reduced dependence on public funds);

— a threefold increase in employment in the R&D sector in absolute terms and an almost twofold increase in relative terms; in 2023, the dominant group in the employment structure were scientific researchers (70%), followed by technicians (21%); changes also affected economic sectors: employment in the business sector increased to 50% (+27 percentage points), while in the government sector it fell to just under 2% (-18 percentage points);
— more than a sevenfold increase in the number of patent applications and a corresponding rise in their share of total EU patent applications (reaching 1%); Poland ranks 7th among EPO member countries in terms of growth dynamics of patent filings and 10th globally; in 2023, most applications concerned medical technologies, pharmaceuticals, and civil engineering, with the highest activity observed among Polish universities and research institutes.

In addition, it is important to mention the policies supporting Poland's international technological competitiveness, encompassing both a holistic approach and actions specifically aimed at technological development. Key documents include the Strategy for Responsible Development (supporting cohesion and economic growth), the Productivity Strategy 2030 (focusing on innovation and modern technologies), the National Smart Specializations (which define priority research areas), and the National Science Policy (promoting knowledge transfer and technological independence). At the national level, notable initiatives are the Minister of Development and Technology's Program supporting new technologies and the SMART Path, offering significant funding for innovative projects. At the EU level, the European Funds for R&D, which have significantly increased innovation funding since 2004, and the European Funds for a Modern Economy Program, with a budget of PLN 4 billion for research and development, are key. The synergy of these initiatives has contributed (and likely continues to contribute) to the dynamic growth of Poland's innovation and international technological competitiveness.

However, there are still barriers that may limit the full potential of the country's technological development. Among the most significant are: (1) dependence on public funding (although Poland has increased its R&D expenditures, a high reliance on public resources remains, which may limit the efficiency of innovative projects), (2) difficulties in commercializing innovations (despite the growing number of patent applications, effectively bringing innovations to market and utilizing them in the private sector remains a challenge), and (3) insufficiently developed collaboration between science and industry (there is a need for closer cooperation between academic institutions and businesses, which would facilitate better implementation of new technologies)..

In light of the above, for Poland to maintain and further develop its technological competitiveness in the future, continued reforms and support for innovation are essential. The key recommendations include: (1) increasing private investment in R&D, primarily through tax incentives and other forms of encouragement; (2) enhancing public-private collaboration between universities, research institutes, and the private sector to accelerate the commercialization of innovations and strengthen knowledge transfer; (3) supporting the start-up sector and innovative enterprises by creating a favorable ecosystem, including easier access to financing and fostering international cooperation; and (4) focusing on areas critical for the future—particularly investing in technologies related to digital transformation, artificial intelligence, biotechnology, and green energy, as these will be pivotal for the country's international competitiveness.

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