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COMPETITIVENESS REPORT
2026

Edited by
Arkadiusz Michał Kowalski
Marzenna Anna Weresa

Research and Development Activity as a Factor of Competitive Advantage

SGH Publishing House

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Reviewers
Professor Robert W. Ciborowski
Professor Andrzej Jasiński

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Preface

Marzenna Anna Weresa, Arkadiusz Michał Kowalski

The debate on the competitiveness of economies, which has gained new momentum in recent years, is increasingly focused on the importance of knowledge, innovation and the ability to respond rapidly to changing global conditions. In the face of escalating geopolitical tensions, the acceleration of the green and digital transitions, growing regulatory pressure, and demographic challenges, factors that foster sustained productivity growth and enable the creation of stable, long-term competitive advantages are becoming particularly important. One of the most significant factors is research and development (R&D), which serves not only as a source of new technologies and innovations but also as the foundation of a knowledge-based economy.

The economic literature on endogenous growth models emphasises that investment in research and development, as well as in human capital, can be a major internal driver of economic growth, enabling countries not only to close the development gap but also to build their own unique competitive advantages. In practice, this translates into the need to pursue a coherent science, technology and innovation (STI) policy focused on strengthening the capacity to generate and absorb knowledge, while effectively linking the R&D system with the needs of the economy and society. In this context, the question arises as to the extent to which the Polish economy is leveraging the potential of R&D, and whether R&D is genuinely becoming a pillar of the country's competitive advantage in European and global markets.

Therefore, the main objective of this monograph is to determine the competitive position of the Polish economy relative to other European Union countries, with particular emphasis on the importance of research and development in shaping Poland's competitiveness. From a theoretical perspective, the publication seeks to enhance our understanding of the relationship between R&D and innovation, on the one hand, and the competitiveness of economies, on the other, particularly in terms of growth. The aim of the empirical research presented here is to identify and assess the impact of R&D on the performance of the Polish economy in terms of foreign trade, productivity, income convergence and innovation, while also diagnosing the institutional and structural factors that facilitate or limit the utilisation of the country's R&D potential.

This monograph forms part of the long-standing publication series of SGH's World Economy Research Institute, titled *Poland. Competitiveness Report*, continuing the

tradition established in earlier editions of analysing Poland's competitiveness relative to other EU countries from two perspectives: competitive position and competitive capacity. The starting point is the assumption that R&D activities influence both of these dimensions – on the one hand, by providing the resources and competencies necessary to create competitive advantages, and on the other, by shaping the economy's performance in terms of foreign trade, productivity and national income.

The structure of the monograph reflects this research logic and is divided into two parts, each comprising several chapters. Part I, titled *Poland's Competitive Position in the European Union: The Role of Research and Development*, focuses on assessing the performance of the Polish economy in relation to other EU countries, with particular emphasis on the role of research and development. Chapter 1 provides the theoretical framework, presenting the evolution of approaches to R&D as a determinant of competitiveness, with particular emphasis on the literature relating to endogenous growth models and the concept of knowledge- and innovation-based advantages. Chapter 2 analyses the R&D activities undertaken by foreign investors in Poland and the other Visegrád Group countries, and examines their importance for the technology and innovation capacity of the host economy. Chapter 3 focuses on the impact of R&D and innovation on Poland's competitiveness in foreign trade. To this end, it examines the extent to which the intensity of R&D activities and the impact of innovation translate into the product and geographical structure of Polish exports, their specialisation, and their ability to compete on the basis of quality and technological sophistication. These analyses are complemented by Chapter 4, which examines the technology intensity of Polish exports of goods. Particular attention is devoted to the share of medium- and high-tech products in exports, as well as to changes in this area compared to other EU countries, with a view to assessing whether Poland is moving towards more advanced segments of global value chains. Chapter 5 addresses the income dimension of competitiveness, analysing Poland's income convergence with respect to EU countries. These considerations are placed within the broader context of the impact of R&D and innovation on economic growth and on narrowing the gap between Poland and more advanced economies. Part I concludes with Chapter 6, which analyses changes in total factor productivity (TFP), with particular focus on the role of research and development. By applying growth accounting methods, the chapter assesses the extent to which Poland's economic growth is driven by increases in labour and capital inputs, as opposed to the improvements in the efficiency of their use, supported in part by R&D activities.

Part II of the monograph – *The Role of Research and Development in Building Competitive Capacity* – focuses on the resources and factors that determine the ability of the Polish economy to create and sustain competitive advantages based on R&D

activities. Chapter 7 analyses the labour market and human capital from the perspective of research and development, discussing the supply of highly qualified personnel, the structure of education, the mobility of knowledge workers, and the alignment of skills with the needs of the R&D sector and innovative sectors of the economy. Chapter 8 examines R&D activities and innovation in the Polish economy from a macro-, meso- and microeconomic perspective. Chapter 9 analyses the importance of R&D as a factor determining the likelihood of introducing product innovations in European small and medium-sized enterprises. Part II concludes with Chapter 10, which focuses on science, technology and innovation (STI) policy.

The monograph concludes with a synthetic summary presenting the most important theoretical and empirical findings, together with recommendations for economic policy, in particular with regard to the use of science, technology and innovation policy instruments in shaping the country's competitiveness. These recommendations concern both the areas in which R&D activities in Poland should be supported and the ways in which the results of these activities can be used to strengthen the economy's long-term competitive advantages.

The authors hope that the *Report* will contribute to the discussion on the role of R&D in shaping the competitiveness of economies and enhance understanding of the challenges and opportunities facing Poland in its efforts to build a knowledge-based economy capable of competing in an evolving international environment.

Part I

Poland's Competitive Position in the European Union: The Role of Research and Development

Chapter 1

Research and Development and Its Role in Competitiveness: A Theoretical Approach

Marzenna Anna Weresa, Arkadiusz Michał Kowalski

1.1. Introduction

In the context of dynamic changes in the global economy, advancing digitalisation, and accelerated technological transformation, research and development (R&D) is becoming one of the key factors determining the long-term competitiveness of enterprises, regions and countries. At the same time, there is growing awareness that the high level of R&D expenditure does not automatically guarantee improved innovation performance or a stronger competitive position unless it is accompanied by appropriate institutional conditions, competencies, and absorptive capacities of the entities involved. Moreover, the structure of R&D activities, encompassing basic and applied research, as well as experimental development, raises questions about balancing knowledge- and application-oriented objectives and about the optimal configuration of these activities for the long-term growth of innovation and competitive advantage.

The aim of this chapter is to examine the theoretical foundations of the relationship between R&D and competitiveness through a discussion of the definitions and classification of research and development activities, the sources of competitive advantage derived from investments in knowledge and innovation, as well as an analysis of the mechanisms through which R&D influences economic growth and international competitiveness. In the economic literature, the role of R&D in enhancing competitiveness is examined from the perspective of various theoretical approaches – from Schumpeter's theory of innovation, through the resource-based view (RBV) of the company, which emphasises the role of unique knowledge resources and technological competencies in building a sustainable competitive advantage, to contemporary theories of endogenous growth. This perspective is further complemented by approaches highlighting the systemic nature of innovation

and the need for collaboration among multiple actors within the so-called triple helix and quadruple helix models. This chapter provides an overview of the literature, thereby establishing the theoretical framework for the empirical analyses of the role of R&D in Poland's economic development.

1.2. The concept of research and development

The *Frascati Manual*, published by the OECD for over 50 years, is the internationally recognised standard for defining and measuring R&D activities. Its most recent edition was published in 2015, followed three years later, in 2018, by a Polish edition. According to the definition proposed in the *Manual*, "R&D comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" [OECD, 2015, p. 28]. According to this definition, a constitutive feature of R&D is its focus on generating new knowledge, irrespective of the intentions behind it. This may include not only the pursuit of economic benefits or solutions to social problems, but also the acquisition of knowledge *per se*.

R&D is characterised by a specific set of common features, regardless of who carries it out. Research and development activities may involve the implementation of both specific and broader objectives. Their purpose is to generate new discoveries based on original concepts, as well as their interpretations or hypotheses. A typical feature of these activities is uncertainty regarding the final results, or at least the time and resources required to achieve them, while the project is planned and budgeted – even if it is carried out by natural persons. Furthermore, it is assumed that the results obtained may be freely transferred or commercialised. In order for a given activity to be classified as R&D, it must meet five basic criteria: it should be novel, creative, uncertain, systematic, and transferable and/or reproducible [OECD, 2015].

The concept of R&D encompasses three main categories of activity: basic research, applied research, and experimental development. However, the sequence of these activities should not be interpreted as implying a linear progression from basic research, through applied research, to experimental development. Indeed, within the R&D system, numerous parallel and reverse flows of information and knowledge exist. For example, experimental development may provide the impetus to undertake basic research, while at the same time the possibility of a direct transition from basic research to the creation of new products or processes remains entirely open.

According to the *Frascati Manual*, basic research is "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations

of phenomena and observable facts, without any particular application or use in view" [OECD, 2015]. Basic research focuses on the analysis of properties, structures and relationships, and its primary objective is to develop and test hypotheses, theories or laws. A key characteristic of this type of research is that it is not linked to a specific application, as at the stage of its implementation researchers may not yet be aware of the potential applications of the results obtained. The results of basic research are generally not commercialised, but are typically disseminated through publications in scientific journals or other forms of knowledge sharing among researchers interested in a given field.

Applied research is defined as "original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective" [OECD, 2015]. The purpose of this type of research is to identify possible applications for the results of basic research, or to establish new methods and approaches for achieving specific, pre-defined objectives. It involves the use of existing knowledge and expanding it with a view to solving specific practical problems. The results of applied research are intended primarily for potential applications in the field of products, operations, methods or systems, thereby giving an operational form to initial ideas. Such applications may be protected through intellectual property instruments, including trade secrets.

Experimental development is defined as "systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes" [OECD, 2015]. Activities aimed at developing new products or processes may be classified as experimental development if they satisfy the criteria applicable to R&D. This includes, *inter alia,* uncertainty regarding the scale and structure of the resources required to achieve the objectives of the R&D project within which experimental development is undertaken.

Within the literature on the subject, the approach presented in the *Frascati Manual* serves as the main reference point for analyses of R&D, although it does not encompass the full range of theoretical perspectives. In recent years, it has been increasingly emphasised that the OECD definition – which highlights the creative and systematic nature of work aimed at expanding the stock of knowledge and developing new applications – has been widely adopted in EU statistics (Eurostat), as well as in UNESCO and US NCSES standards, thereby supporting the comparability of data at an international level. At the same time, attention is drawn to the need to continuously refine the boundaries between R&D and other knowledge-based activities, such as routine engineering work, testing or implementation [UNESCO, 2025]. It is also noted that the application of methods for identifying and measuring R&D often requires

precise survey tools and detailed sector-specific guidelines, e.g. in the IT sector [Galindo-Rueda, López-Bassols, 2022].

The tripartite division into basic research, applied research, and experimental development is also the subject of scholarly debate. Empirical research shows that in practice, the boundaries between these categories are fluid, and many researchers combine elements of all three types of activity in their work. Gulbrandsen and Kyvik [2010] point out that the traditional tripartite division is still useful as a heuristic, but is less effective in capturing the hybrid nature of contemporary research projects, in which knowledge- and application-oriented motivations coexist. More recent studies on the strategic research agendas of scientists demonstrate that preferences for basic research, applied research, and experimental development vary significantly across disciplines and countries, and that researchers' choices are shaped by both institutional norms and financial incentives [Santos, Horta, Luna, 2022]. In this context, it is recommended that the typology from the *Frascati Manual* be treated as a continuum rather than as a set of separate categories, which is consistent with the non-linear nature of knowledge flows within the R&D system.

A key aspect of the current debate is also the relationship between R&D and innovation, defined in the *Oslo Manual* [OECD, 2018] as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". The literature emphasises that not all manifestations of innovative activities are related to R&D (e.g. innovations based on the acquisition of off-the-shelf technology), while, at the same time, some R&D work may not contribute to the creation of innovations, especially in the short term. Consequently, the distinction between R&D and innovation appears crucial when analysing the role of R&D from the perspective of competitiveness, as misclassification may lead to overestimating or underestimating the role of R&D in innovation processes.

The consequences of the adopted definitions and classification criteria are evident in research on the relationships between R&D intensity[1] and productivity, innovation, and the export performance of enterprises. Recent empirical evidence indicates that the relationship between R&D expenditure and innovation performance is complex, depending on sectoral conditions, management quality, and complementary knowledge resources, making straightforward interpretations of R&D intensity indicators difficult. Saharti [2025] analyses a panel of 252 listed companies from G7 countries, examining the impact of R&D intensity, the relationship to assets, and the dynamics of R&D

[1] From a microeconomic perspective, R&D intensity is defined as the ratio of internal R&D expenditure to total net sales revenue.

activity on labour productivity (efficiency) and asset turnover. The study confirms the positive impact of innovation on productivity, while also revealing a negative relationship between innovation and asset turnover. This phenomenon is interpreted as a short-term cost in terms of operational efficiency resulting from an aggressive R&D strategy. The findings suggest that the assessment of returns on R&D activities should take into account both the multidimensional nature of a company's efficiency and the varying sectoral conditions and level of profitability.

A good example of the implications of the adopted definitions and the operationalisation of R&D intensity is provided in a study by Guo, Gao and Cheng [2023], which was conducted on 1,808 Chinese manufacturing companies operating between 2006 and 2015. The study distinguishes between overall R&D intensity and the intensities of research and development measured separately as the share of the corresponding expenditures in the enterprise's tangible assets. The authors identify an S-shaped relationship between R&D intensity and productivity: once the share of R&D in capital exceeds approx. 50%, the marginal effect becomes negative. An increase in research intensity raises productivity to a saturation point of approx. 65%, whereas development intensity follows an inverted U-shaped pattern, with negative marginal effects emerging above approx. 28% and a turning point at approx. 35%. The main conclusion is that the components of R&D activities should be optimised by increasing the share of research relative to excessive development expenditure, as the imbalance typical of the surveyed companies reduces the effectiveness of expenditure and productivity growth. At the same time, development activities retain a significant advantage in terms of market relevance and their direct link to the commercialisation of innovation.

1.3. Sources of competitive advantage arising from investments in research and development

The competitiveness of an economy is a multidimensional concept, encompassing not only its ability to generate high and growing incomes but also its position in international trade, investment attractiveness, innovation, and the quality of its institutional, social and environmental frameworks. From this perspective, competitiveness extends beyond achieving an advantage in foreign markets, and encompasses the ability to continuously improve social welfare through the efficient use of available resources.

One of the key dimensions of international competitiveness is income competitiveness, understood as the ability of an economy to generate a level of income that enables a sustained improvement in the quality of life of its population. The primary measures of income competitiveness relate to gross domestic product (GDP),

in particular GDP *per capita* at purchasing power parity, which remains one of the most widely used macroeconomic indicators. For many years, it has served as a tool for classifying countries as developed or developing, illustrating the scale of disparities in the level of socio-economic development [Kowalski, 2025].

The international dimension of competitiveness is reflected in a country's economic links with the global economy, which can be considered collectively or by highlighting two key components: foreign trade competitiveness and investment competitiveness. Foreign trade remains the most frequently analysed form of economic links. In this context, competitiveness refers to the ability to sell domestically produced goods and services in foreign markets [Misala, 2014; Weresa, Kowalski, 2025]. From a static perspective, competitiveness in international trade essentially refers to a country's relative (comparative) advantages, which, through appropriately implemented economic policies, can be transformed into dynamic competitive advantages.

International flows of inputs, in particular foreign direct investment, constitute the second key dimension of international competitiveness, namely investment competitiveness. This refers to a country's ability to attract foreign inputs, especially capital, and to derive benefits from the transfer and effective use of domestic inputs abroad. In this sense, investment competitiveness reflects both the attractiveness of an economy to foreign investors and the ability of domestic entities to invest abroad [Kowalski, Weresa, 2021].

R&D is most closely linked to the technological dimension of competitiveness. In the literature, technological competitiveness is defined as the ability of an economy or enterprise to transform R&D expenditure into technological advantages, as evidenced, *inter alia,* by the strength of high-tech sectors, patent intensity, exports of high-tech products, and productivity growth [Weresa, 2019]. This is particularly relevant in light of recent research emphasising that technological competitiveness depends not only on the level of R&D expenditure, but above all on the ability to translate this expenditure into measurable innovation outcomes. In this context, Belanová, Ochotnický and Sivák [2025] highlight the risk of the so-called R&D trap, where increasing R&D expenditure does not lead to a proportional improvement in innovation performance and competitive position. According to these authors, this is illustrated by the case of Slovakia, where despite a relatively high increase in total factor productivity (TFP), particularly after 2015, the pace of the country's convergence with the EU in terms of GDP *per capita*, expressed in purchasing power parity (PPP), has slowed, while R&D remains consistently underfunded (GERD below 1% of GDP, compared with an EU average of just over 2%). This creates the risk of a systemic "R&D trap", demonstrating that it is not enough to simply increase R&D expenditure. The key factors in this case are the mechanisms through which this expenditure impacts innovation, which, however,

cannot function properly due to, *inter alia,* the low attractiveness of the research system and weak links within the national innovation system. Consequently, increasing R&D expenditure without a profound change in the ecosystem, represented by the quintuple helix model, does not generate a proportional improvement in innovation performance and competitiveness, but instead perpetuates a development path based on traditional advantages (e.g. cost advantages) rather than on innovation.

Recent literature on the subject [e.g. OECD, 2024] emphasises that digital technologies are becoming one of the main drivers of contemporary structural change and shifts in the formation of competitive advantages, while also constituting a key area of R&D investment within national innovation systems. In the context of innovation policy, these technologies are classified as key enabling technologies, contributing to the development of successive generations of product and process innovations and enhancing economies of scale and scope in both manufacturing and services. In this context, in addition to the traditional dimension of technological competitiveness, digital competitiveness is increasingly recognised as a distinct concept, defined as the ability of an economy to adopt, develop through R&D activities, absorb, and use digital technologies as a key factor in transforming business models, governance practices and the functioning of society [Martinčević, 2022].

Investments in R&D can also be seen as a key source of competitive advantage within the resource-based view (RBV) framework [Barney, 1991], as they contribute to the accumulation of resources in the form of knowledge, technology, patents, routines and competencies that are valuable, rare, difficult to replicate, and embedded in an appropriately organised structure. Long-term, cumulative R&D expenditure creates a unique "knowledge core" for a company or an economy, forming the basis for a sustainable cost and quality advantages in international markets [Helfat et al., 2023]. Zaman and Tanewski [2024], referring directly to RBV, demonstrate that R&D intensity and the ability to generate product and process innovations constitute strategic resources that determine export advantage, although their productive utilisation varies significantly between SMEs and large companies. In turn, Du, Kim, Fan and Su [2025] analyse different slack configurations to demonstrate that specific configurations of financial and organisational resources support high R&D intensity in fast-growing companies, thereby confirming the complementarity of R&D with other strategic resources.

One of the most frequently used frameworks for analysing the international competitiveness of economies, sectors and regions is Porter's diamond of competitive advantage [Porter, 2008], which indicates that competitive advantage arises from the interaction between factor conditions, demand conditions, the existence of related and supporting industries, and the companies' structure and rivalry. These determinants

are complemented by the role of government and chance events, which can strengthen or weaken the impact of the above components. Among the so-called factor conditions, a significant role is played by the knowledge infrastructure and the R&D ecosystem, comprising the higher education system, research institutions, technology parks and specialised human capital resources, which determine an economy's ability to generate and absorb innovation [Lehene, Jaradat, Nistor, 2024]. At the same time, competitive advantage based on R&D is closely linked to the development of clusters that make intensive use of R&D in specialised technological fields, thereby significantly contributing to productivity growth [Kosfeld, Mitze, 2023].

More recent theoretical approaches combine Porter's diamond model of competitive advantage with the resource-based view (RBV), suggesting that competitive advantages derived from local conditions (e.g. R&D infrastructure, quality of human capital, and institutions) materialise only when companies possess the appropriate resources and capabilities to utilise these conditions. Andy, Ayavoo and Idris [2025] propose an integrated approach combining Porter's diamond model of competitive advantage, the resource-based view, and Dunning's concept of international production [1988]. Their analysis demonstrates that developed factor conditions, including access to specialised knowledge resources and R&D, enhance the attractiveness of a location, but that competitive advantage only emerges in combination with companies' internal resources and capabilities.

1.4. Research and development, innovation, growth, and competitiveness – theoretical links

In the traditional view, an economy is considered competitive if it creates conditions that ensure the sustained productivity growth and an increase in the level of social welfare within the framework of an open economy [Porter, 2008, p. 176]. Adopting such a broad definition, which focuses on the so-called **income dimension of competitiveness** [Kowalski, Weresa, 2021], entails expanding theoretical considerations on the relationship between R&D and competitiveness to include insights derived from economic growth theory. As indicated in the literature, R&D constitutes one of the key drivers of innovation influencing productivity, economic growth and competitiveness [Porter, 2008], which implies that innovation is the principal channel through which R&D impacts growth and competitiveness.

The relationship between innovation and economic development was recognised already in classical economic theories, although it initially received only marginal attention. In contemporary literature, these relationships are analysed primarily within

the framework of selected approaches to economic growth theory (evolutionary and neoclassical approaches, endogenous growth theory), which emphasise the importance of technological progress and innovation in different ways.

The origins of the analysis of innovation in the context of economic growth and competitive advantages can be traced to the work of Joseph Schumpeter [1912], regarded as a pioneer in the field of evolutionary economics [Edquist, McKelvey, 2000]. In his view, innovation and, more broadly, knowledge constitute microeconomic factors of development, shaped by individual entrepreneurs through the accumulation of experience and capabilities. A company's accumulated knowledge base determines its competitive advantage, while the innovative behaviour of individuals, combined with market selection mechanisms, generates macroeconomic growth dynamics. Economic development is therefore understood as the result of continuous structural changes generated within the economic system and rooted in developments occurring in earlier periods [Schumpeter, 1960], which constitutes a key feature of the evolutionary approach.

Technological progress, as an exogenous factor of economic growth, occupies a central place in neoclassical growth theories. In Robert Solow's model [1956], economic growth results from the accumulation of capital and labour, while technology is not the outcome of companies' actions but an exogenous driving force of development. In line with the neoclassical paradigm, this theory is based on the assumption of perfect competition, with no externalities, as well as diminishing marginal productivity of inputs and the homogeneity of the production function. The implication of this approach for the analysis of competitiveness is the assumption that the competitive advantage of economies does not stem from their internal capacity to create and implement innovation, but from external technological factors. Consequently, in the neoclassical model, all economic operators have access to the same technologies, while differences in their level of competitiveness arise solely from the efficiency with which their inputs are used. Competition therefore essentially concerns the optimal allocation of resources, rather than the ability to generate technological progress, the latter treated as an exogenous factor. Such an understanding of the role of technology limits our understanding of the mechanisms through which investments in research, knowledge and human capital can become a source of sustainable competitive advantage.

In response to the limitations of the neoclassical approach, endogenous growth models emerged, emphasising the role of internal factors – particularly innovation, knowledge and human capital – in generating long-term growth. Endogenous growth theorists rejected the assumptions of the neoclassical approach, instead considering technological progress as an endogenous factor. A precursor of this theoretical approach was Paul Romer [1990], who demonstrated that innovation, understood as

the introduction of new products and production methods, is the result of investment in R&D. Romer's growth model encompasses three sectors of the economy: the research sector, the intermediate goods sector, and the final goods sector. The output of the research and development sector is knowledge, created by researchers on the basis of the existing stock of knowledge. Within the production sector, new ideas serve two functions: they enable the creation of new goods and services, and they enhance the effectiveness of future research. Owners of innovations obtain temporary exclusive rights to their commercial use, while knowledge continues to generate spillover effects that facilitate further research and innovation [Romer, 1990]. In Romer's model, knowledge and innovation are therefore the primary sources of long-term economic growth. The process of knowledge accumulation, supported by investment in R&D and appropriate market incentives, leads to a sustained increase in productivity and economic competitiveness [Jones, Romer, 2009].

From this perspective, technological progress and innovation are the result of purposeful activities by economic operators, including investment in research and development. R&D contributes to increased productivity and the export expansion of enterprises [Grossman, Helpman, 1991], meaning that innovation contributes to achieving sustained economic growth and **international competitiveness (in foreign trade)**, understood as the ability to sell goods and services in international markets.

An approach that emphasises not only the introduction of entirely new solutions but also the improvement of existing products represents a further development of the concept of endogenous growth [Aghion, Howitt, 1992, 2009; Aghion, Akcigit, 2017]. This concept draws on Schumpeter's notion of creative destruction, whereby the introduction of innovations leads to the replacement of old technologies with new ones. Contemporary research on innovation and economic growth increasingly emphasises the importance of dynamic processes in which technological progress, competition, and public policy interact with one another. Competition – including intellectual competition linked to scientific development and research – as well as broader cultural factors such as openness and pluralism, contribute to the foundations of sustainable economic growth, as demonstrated by historical analyses [Mokyr, 2016]. The impact of cultural factors on innovation, productivity, and competitiveness is also confirmed by bibliometric analyses of scientific papers published between 2009 and 2018 [Chen, Lin, 2021]. Along with trust and the ability to cooperate, cultural factors constitute important components of **relational competitiveness** [Kowalski, Weresa, 2021].

In the context of the above considerations, the implications of this approach for the competitiveness of economies appear to be particularly significant. In endogenous models, competitive advantage is not the result of external technological determinants, but rather of an economy's ability to continuously generate, absorb and improve

knowledge, thereby highlighting **the technological dimension of competitiveness** [Kowalski, Weresa, 2021]. Economies that create conditions conducive to investment in research, education, human capital and a culture of openness to innovation achieve a sustainable competitive advantage because they are able to respond more rapidly to technological and structural change. Conversely, countries with low levels of innovation and weak institutions supporting research and development are more vulnerable to stagnation, declining productivity, and a loss of position in the global division of labour. Consequently, from the perspective of the endogenous growth theories, the long-term competitiveness of economies is a direct result of their innovative and institutional capabilities, rather than merely of the level of capital accumulation or labour resources. As emphasised by Ciborowski [2012], in the context of globalisation technological advantage is determined not only by the level of domestic R&D expenditure, but also by the ability to effectively integrate into international knowledge and technology flows and to use technology transfer as a key channel of productivity convergence. From an endogenous perspective, and in light of the global determinants of technological progress, technological competitiveness therefore depends on both internal innovation capabilities and the way in which the economy is integrated into global knowledge creation and diffusion networks. At the same time, an economy's innovative capacity is a function not only of the activity of enterprises themselves, but also of the quality of innovation policy and the design of the support instruments used, which can either reinforce or slow down the processes of learning and knowledge diffusion [Jasiński, 2014].

To explain the concept of **sustainable competitiveness**, which encompasses not only increasing prosperity but also social and environmental issues [Corrigan, Crotti, Drzeniek Hanouz, Serin, 2014; Kowalski, Weresa, 2021], the conclusions drawn from analyses of economic development based on Schumpeter's concept of competition are highly relevant. Within this framework, companies compete for technological primacy through investment in R&D and the ability to adapt more rapidly, with issues such as the sources of growth and inequality, competition and globalisation, as well as factors affecting health and well-being, technological revolutions, the middle income trap, climate change, and responses to economic shocks also playing a significant role [Aghion, Antonin, Bunel, 2021]. In the development model proposed by Aghion, inclusive and sustainable growth may be viewed as compatible and potentially mutually reinforcing goals. Improvements in the quality of life result from the creation and implementation of innovations within a market economy. However, this process requires active involvement from the state and well-functioning institutions to monitor and maintain a balance between supporting ongoing creativity and entrepreneurship, on the one hand, and mitigating the negative social impacts of the innovation process on the other

[Aghion et al., 2021]. One such consequence may be economic and social inequality. Innovation fosters productivity growth and the creation of high-quality jobs, but it may also increase the incomes of the wealthiest segments of society through so-called innovation rents. The impact of innovation on inequalities is therefore ambivalent, as it can both intensify and reduce them depending on the nature of the innovation, the structure of intellectual property rights, and the institutional framework of the market. In this context, the importance of active government policy is emphasised, in particular the design of competition policy, taxation systems, and regulations restricting lobbying in such a way that innovation supports inclusive growth involving broad public participation in the benefits of development [Aghion, Griffith, 2024], which forms part **of the dimension of sustainable competitiveness**.

In summary, R&D is a process shaped by complex interdependencies between internal and external factors, including the availability of funding, staff expertise, the efficiency of R&D organisation, a supportive regulatory and institutional environment, and the availability and quality of research infrastructure. The interrelationships between these elements determine an economy's ability to create, absorb and commercialise knowledge, thereby influencing its level of innovation and competitiveness. Integrating these factors within a coherent innovation ecosystem enables an economy not only to maintain its competitiveness but also to develop new sources of growth based on knowledge, technology, and collaboration. The success of R&D depends on both individual social actors and the systemic interactions between them. Synergies among these areas foster knowledge transfer, the commercialisation of research results, and the development of innovative regional ecosystems. These relationships are summarised in the triple helix model of innovation [Etzkowitz, Leydesdorff, 2000; Etzkowitz, 2008]. Contemporary approaches extend this model to include a fourth helix (quadruple helix), which includes society and end users as active participants in innovation processes [Carayannis, Campbell, 2009]. As a result, innovation becomes more inclusive and better aligned with social needs, thereby increasing its acceptance and implementation potential. From the perspective of economic competitiveness, networked and interactive links between science, business, government and society are crucial for the effective functioning of the innovation system. The stronger the relationships within the innovation system, the greater a country's capacity to generate knowledge, transform it into innovation, and build lasting competitive advantages based on technology and knowledge.

Another factor influencing the R&D sphere is the institutional environment. The functioning of R&D within a market economy depends heavily on the quality of the institutional framework, which includes, *inter alia,* regulations supporting R&D activities by enterprises, the intellectual property protection system, the rules governing

cooperation between companies and universities, the scope of public research funding, as well as the stability of the legal system and the transparency of procedures that create a framework conducive to investment in knowledge and development [Nelson, 2005]. From this perspective, the state becomes an active participant in the R&D system and the innovation process, not only through the establishment of a regulatory framework, but also through supporting the development and diffusion of knowledge through appropriate regulations and innovation policy instruments.

The integration of the technological and institutional dimensions in the analysis of the relationships linking R&D, innovation and economic growth formed the basis for the development of the concept of national innovation systems, which emphasises the importance of interactions between businesses, academia, and public administration [Freeman, 1982; Lundvall, 1992; Nelson, Rosenberg, 1993; Jasiński, 1997; Nelson, 2005; Weresa, 2012; Jasiński, 2021].

In summary, an analysis of the literature on the subject indicates that the factors influencing R&D include funding, human resources, and organisational aspects, all of which shape the ability of research institutions and enterprises to conduct effective research activities. Financial factors determine both the scale and stability of investment in research and development. Access to private capital (e.g. venture capital and private equity) as well as public capital (grants, tax incentives, and structural funds) influences the ability to undertake long-term, high-risk projects. Stable financing is particularly important in the context of basic research, the effects of which become visible over the longer term and form the foundation for future innovation.

Another key element of the R&D sphere is human capital, including the skills, creativity and ability of employees to adapt to technological change. Highly qualified researchers, engineers, innovation managers and data analysts constitute a strategic asset determining the quality and productivity of R&D processes. In this context, not only the level of education, but also professional mobility, cross-sectoral collaboration, and the development of soft skills that foster the co-creation of knowledge and innovation become increasingly important.

From an organisational perspective, management structures that support interdisciplinary and international collaboration, flexibility, and a culture of innovation are crucial. Effective research organisations and innovative companies are characterised by openness to experimentation, rapid information flows, and the ability to absorb external knowledge. High-quality R&D project management – encompassing planning, cost control, risk assessment, and the effective use of results – constitutes a key success factor.

Another essential factor supporting R&D activities is innovation infrastructure, which encompasses both physical resources (laboratories, research centres, broadband

networks, technological facilities) and intangible resources, including scientific information systems, databases, technical standards, and norms. High-quality infrastructure enhances opportunities for collaboration between research institutions and the business sector, thereby shortening the innovation cycle and accelerating the implementation of research results.

Public policy, including science, technology and innovation policy, influences the R&D sphere through financial, regulatory and institutional instruments, thereby shaping the direction and dynamics of R&D activities [Edler, Fagerberg, 2017; Borrás, Edler, 2020; Weresa, 2022; Einhoff, Paunov, 2025]. The adoption of a long-term strategy in this regard enables a more effective allocation of resources to the areas with the greatest potential for increasing productivity and competitiveness.

1.5. Conclusions

The analysis conducted in this chapter demonstrates that R&D is a complex phenomenon requiring precise definitions and measurement tools. It should be noted, however, that the boundaries between R&D and other knowledge-based activities remain fluid, creating a risk of misclassification. The findings of the cited empirical studies indicate that the relationship between R&D expenditure, productivity and innovation is not linear. Of particular importance are the structure of R&D activities – the relationship between research and development work – and their complementarity with other resources, including organisational, financial and human capital. This suggests that the outcomes of R&D activities are determined not only by factors such as the level of their advancement, but also by the quality of management and the broader industry context.

The strategic importance of R&D stems from the unique nature of this field, which combines two dimensions: the knowledge-oriented and the application-oriented. On the one hand, it enables the expansion of the boundaries of knowledge, while on the other, it provides the foundations for the development of product, process and organisational innovations. From the perspective of international competitiveness, R&D constitutes a key source of technological and digital advantages, influencing an economy's ability to generate high incomes, strengthen its export position, and enhance its investment attractiveness. According to the resource-based view, cumulative investment in research and development creates a unique knowledge core that can form the basis for a long-term competitive advantage. This approach aligns well with Porter's diamond model, in which a well-developed R&D infrastructure, specialised

human capital, and strong technology clusters strengthen the local determinants of competitive advantage.

Effective R&D is not only a driver of technological development, but also a mechanism for building resilience and long-term competitiveness of the economy. Contemporary economic theories recognise R&D as a complex process of knowledge creation and utilisation, the significance of which has evolved alongside the development of growth and competitiveness theories. From Schumpeter's view of innovation as the driving force behind "creative destruction", through endogenous growth models that emphasise the role of knowledge and technology accumulation, to contemporary resource-based economy concepts, R&D is regarded as a strategic component of building competitive advantage based on the intangible assets of enterprises and economies.

Contemporary frameworks for analysing the role of R&D in the context of economic competitiveness emphasise the interactive and systemic nature of research and innovation processes, highlighting that technological development and the capacity to create innovation are not the result of the actions of individual entities, but rather emerge from collaboration between the various participants in the ecosystem, including research institutions, enterprises, public administration and civil society. These interdependencies are described by contemporary collaboration models, referred to as the triple and quadruple helix, which emphasise the importance of partnerships, knowledge exchange, and the co-creation of innovation to enhance economic competitiveness. In a world characterised by an ever-increasing speed of technological change and global challenges, the ability to create, adapt and diffuse knowledge is becoming a valuable asset for countries, regions and businesses. The integration of organisational, institutional and social factors into a single, coherent innovation ecosystem is therefore important for shaping a modern, sustainable and resilient economy of the future.

References

Aghion, P., Akcigit, U. (2017). Innovation and Growth: The Schumpeterian Perspective. In: *Economics Without Borders. Economic Research for European Policy Challenges* (pp. 29–72), M. Ivaldi, R. Blundell, E. Cantillon, B. Chizzolini, W. Leininger, R. Marimon, L. Matyas, F. Steen (Eds.). Cambridge University Press. DOI: 10.1017/9781316636404.003.

Aghion, P., Antonin, C., Bunel, S. (2021). *The Power of Creative Destruction: Economic Upheaval and the Wealth of Nations*. Cambridge: Harvard University Press. DOI: 10.2307/j.ctv33mgbqt.

Aghion, P., Griffith, R. (2024). Innovation and Inequalities, *Oxford Open Economics*, 3(1), pp. 1002–1005. DOI: 10.1093/ooec/odad057.

Aghion, P., Howitt, P. (1992). A Model of Growth Through Creative Destruction, *Econometrica*, 60(2), pp. 323–351. DOI: 10.2307/2951599.

Aghion, P., Howitt, P. (2009). *The Economics of Growth*. London: The MIT Press.

Andy, A., Ayavoo, R., Idris, A. (2025). Factor Conditions and Firm Resources Implications on Location Attractiveness: A Critical Assessment and Application in Shared Services Industry, *African Journal of Science, Technology, Innovation and Development*, 17(4), pp. 609–621. DOI: 10.1080/20421338.2024.2437229.

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage, *Journal of Management*, 17(1), pp. 99–120. DOI: 10.1177/014920639101700108.

Belanová, K., Ochotnický, P., Sivák, R. (2025). Innovation Performance of EU Countries in Context of R&D: R&D Trap Risk in Slovakia?, *Journal of Innovation and Entrepreneurship*, 14(1), p. 59. DOI: 10.1186/s13731-025-00533-5.

Borrás, S., Edler, J. (2020). The Roles of the State in the Governance of Socio-Technical Systems' Transformation, *Research Policy*, 49(5), 103971. DOI: 10.1016/j.respol.2020.103971.

Carayannis, E.G., Campbell, D.F.J. (2009). 'Mode 3' and 'Quadruple Helix': Toward a 21st Century Fractal Innovation Ecosystem, *International Journal of Technology Management*, 46(3), pp. 201–234. DOI: 10.1504/ijtm.2009.023374.

Chen, S., Lin, N. (2021). Culture, Productivity and Competitiveness: Disentangling the Concepts, *Cross Cultural and Strategic Management*, 28(1), pp. 52–75. DOI: 10.1108/CCSM-02-2020-0030.

Ciborowski, R. (2012). Zmiany w charakterze procesów innowacyjnych a konkurencyjność gospodarki, *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Poznaniu*, 246, pp. 11–21.

Corrigan, G., Crotti, R., Drzeniek Hanouz, M., Serin, C. (2014). Assessing Progress Toward Sustainable Competitiveness. In: *Global Competitiveness Report 2014–2015* (pp. 53–83), K. Schwab (Ed.). Geneva: World Economic Forum.

Delgado, M., Ketels, Ch., Porter, M.E., Stern, S. (2012). The Determinants of National Competitiveness, *NBER Working Paper*, 18249. DOI: 10.3386/w18249.

Du, Y., Kim, P.H., Fan, D., Su, Y. (2025). Zooming In and Out for Strategic Advantage: Slack Configurations and R&D Investments in High-Growth Firms, *Journal of Business Research*, 201, 115729. DOI: 10.1016/j.jbusres.2025.115729.

Dunning, J.H. (1988). The Eclectic Paradigm of International Production: A Restatement and Some Possible Extensions, *Journal of International Business Studies*, 19(1), pp. 1–31. DOI: 10.1057/palgrave.jibs.8490372.

Edler, J., Fagerberg, J. (2017). Innovation Policy: What, Why, and How, *Oxford Review of Economic Policy*, 33(1), pp. 2–23. DOI: 10.1093/oxrep/grx001.

Edquist, C., McKelvey, M. (Eds.) (2000). *Systems of Innovation: Growth, Competitiveness and Employment* (Vol. 1–2). Cheltenham – Northampton: Edward Elgar.

Einhoff, J., Paunov, C. (2025). Innovation Policy Transformed?: Unveiling a New Paradigm Through Natural Language Processing, *OECD Science, Technology and Industry Working Papers*, 21. DOI: 10.1787/5ee60cb5-en.

Etzkowitz, H. (2008). *The Triple Helix: University – Industry – Government Innovation in Action*. London – New York: Routledge. DOI: 10.4324/9780203929605.

Etzkowitz, H., Leydesdorff, L. (2000). The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple Helix of University – Industry – Government Relations, *Research Policy*, 29, pp. 109–123. DOI: 10.1016/S0048-7333(99)00055-4.

Freeman, Ch. (1982). *The Economics of Industrial Innovation*. London: F. Pinter.

Galindo-Rueda, F., López-Bassols, V. (2022). Implementing the OECD Frascati Manual: Proposed Reference Items for Business R&D Surveys, *OECD Science, Technology and Industry Working Papers*, 03. DOI: 10.1787/d686818d-en.

Guo, Y., Gao, P., Cheng, D. (2023). The Effects of R&D and Its Different Types on Firm Productivity: Evidence from China, *International Journal of Innovation Management*, 26(8). DOI: 10.1142/S1363919622500657.

Grossman, G.M., Helpman, E. (1991). Trade, Knowledge Spillovers, and Growth, *European Economic Review*, 35(2–3), pp. 517–526. DOI: 10.1016/0014-2921(91)90153-A.

Helfat, C.E., Kaul, A., Ketchen, D.J., Barney, J.B., Chatain, O., Singh, H. (2023). Renewing the Resource-Based View: New Contexts, New Concepts, and New Methods, *Strategic Management Journal*, 44(6), pp. 1357–1390. DOI: 10.1002/smj.3500.

Jasiński, A.H. (1997). New Developments in Science – Industry Linkages in Poland, *Science and Public Policy*, 24(2), pp. 93–99. DOI: 10.1093/spp/24.2.93.

Jasiński, A.H. (2014). *Innowacyjność w gospodarce Polski. Modele, bariery, instrumenty wsparcia*. Warszawa: Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego.

Jasiński, A.H. (2021). *Współczesna scena innowacji. Wyzwania dla przedsiębiorców i menedżerów*. Warszawa: Poltext.

Jones, Ch.I., Romer, P.M. (2009). The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital, *NBER Working Paper*, 15094. DOI: 10.3386/w15094.

Kosfeld, R., Mitze, T. (2023). Research and Development Intensive Clusters and Regional Competitiveness, *Growth and Change*, 54(4), pp. 885–911. DOI: 10.1111/grow.12676.

Kowalski, A.M. (2025). *Clusters and Cluster Policy Models. Driving Competitiveness in the Global Economy*. Cheltenham – Northampton: Edward Elgar. DOI: 10.4337/9781035333981.

Kowalski, A.M., Weresa, M.A. (2021). International Competitiveness and Cooperation in Times of Economic Crises – Theoretical Aspects. In: *Poland. Competitiveness Report 2021. Bilateral Economic Cooperation and Competitive Advantages* (pp. 13–26), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Lehene, C.F., Jaradat, M., Nistor, R.L. (2024). An Interdisciplinary and Multilevel Analysis of Local Economy Determinants and Their Impact on Firm Performance – Considering Porter's Diamond Model, Clusters, and Industry, *Systems*, 12(3), p. 82. DOI: 10.3390/systems 12030082.

Lundvall, B.Å. (Ed.). (1992). *National Systems of Innovation, Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Martinčević, I. (2022). The Correlation Between Digital Technology and Digital Competitiveness, *International Journal for Quality Research*, 16, pp. 541–558. DOI: 10.24874/IJQR16.02-13.

Misala, J. (2014). Theoretical Grounds of the Development of Long-Term Competitive Advantages in International Trade. In: *Innovation, Human Capital and Trade Competitiveness. How Are They Connected and Why Do They Matter?* (pp. 3–51), M.A. Weresa (Ed.). Cham: Springer.

Mokyr, J. (2016). *A Culture of Growth: The Origins of the Modern Economy*. Princeton: Princeton University Press. DOI: 10.1515/9781400882915.

Nelson, R. (2005). *Technology, Institutions and Economic Growth*. Cambridge: Harvard University Press.

Nelson, R. (Ed.). (1993). *National Innovation Systems, A Comparative Analysis*. Oxford: Oxford University Press.

Nelson, R., Rosenberg, N. (1993). Technical Innovation and National Systems. In: *National Innovation Systems: A Comparative Study* (pp. 3–22), R. Nelson (Ed.). New York: Oxford University Press.

OECD (2015). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities*. Paris: OECD Publishing. DOI: 10.1787/9789264239012-en.

OECD (2024). *OECD Digital Economy Outlook 2024. Volume 1: Embracing the Technology Frontier*. Paris: OECD Publishing. DOI: 10.1787/a1689dc5-en.

OECD, Eurostat (2018). *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation* (4th ed.). Paris: OECD Publishing.

Porter, M.E. (2008). *On Competition*. Cambridge: Harvard Business School Publishing.

Romer, P. (1990). Endogenous Technological Change, *Journal of Political Economy*, 98(5), pp. 71–102. DOI: 10.1086/261725.

Saharti, M. (2025). R&D and Innovation and Its Impact on Firm Performance and Market Value: Panel Evidence from G7 Economies, *Economies*, 13(9), p. 254. DOI: 10.3390/economies13090254.

Santos, J.M., Horta, H., Luna, H. (2022). The Relationship Between Academics' Strategic Research Agendas and Their Preferences for Basic Research, Applied Research, or Experimental Development, *Scientometrics*, 127(7), pp. 4191–4225.

Schumpeter, J.A. (1912). *Theorie der Wirtschaftlichen Entwicklung*. Leipzig: Duncker und Humbolt.

Schumpeter, J.A. (1960). *Teoria rozwoju gospodarczego*. Warszawa: Wydawnictwo Naukowe PWN.

Solow, R. (1956). A Contribution to the Theory of Economic Growth, *The Quarterly Journal of Economics*, 70(1), pp. 65–94. DOI: 10.2307/1884513.

Weresa, M.A. (2012). *Systemy innowacyjne we współczesnej gospodarce światowej*. Warszawa: Wydawnictwo Naukowe PWN.

Weresa, M.A. (2019). Technological Competitiveness of the EU Member States in the Era of the Fourth Industrial Revolution, *Economics and Business Review*, 5(3), pp. 50–71. DOI: 10.18559/ebr.2019.3.4.

Weresa, M.A. (2022). *Polityka innowacyjna. Nowe tendencje w teorii i praktyce*. Warszawa: Wydawnictwo Naukowe PWN.

Weresa, M.A., Kowalski, A.M. (2025). Global Value Chains and Competitiveness – A Theoretical Approach. In: *Poland. Competitiveness Report 2025. Reconfiguring Global Value Chains and Shaping Competitive Advantages* (pp. 15–29), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House. DOI: 10.33119/978-83-8030-743-8_2025.

Zadegan, M.G., Ghazinoory, S., Nasri, S. (2025). The Triple Helix Model of Innovation and Sustainable Development Goals: A Literature Review, *Sustainable Development*, 33, pp. 1482–1497. DOI: 10.1002/sd.70041.

Zaman, M., Tanewski, G. (2024). R&D Investment, Innovation, and Export Performance: An Analysis of SME and Large Firms, *Journal of Small Business Management*, 62(6), pp. 3053–3086. DOI: 10.1080/00472778.2023.2291363.

Chapter 2

Research and Development of Foreign Investors in Poland Compared with the Visegrád Group

Tomasz Marcin Napiórkowski

2.1. Introduction

Research and development (R&D), understood in this study as a form of investment, constitutes a key component of technology accumulation, alongside human capital, which represents primarily – but not exclusively – knowledge. Technology accumulation, in turn, forms the basis for economic development, particularly in developed countries [Liu, 2016], according to endogenous theories of economic growth [Lucas, 1988; Romer, 1990; Aghion, Howitt, 1992]. A parallel factor supporting economic development, despite certain controversies [e.g. Agosin, Machado, 2005], is foreign direct investment (FDI) [Napiórkowski, 2017], which contributes to raising the technological level of the host economy. Furthermore, FDI affects the host economy through the following direct and indirect mechanisms (e.g. through links in domestic value chains) [Ha, Holmes, Tran, 2022]:

1) increasing investment in tangible capital [Tang, Selvanathan, Selvanathan, 2008; Miao, Borojo, Yushi, Desalegn, 2021; Sucubasi, Trenovski, Imeri, Merdzan, 2021], especially in the long term [Adams, 2009],
2) stimulating the labour market [Boghean, State, 2015; Hale, Xu, 2016; Perić, Stanišić, 2020],
3) facilitating knowledge transfer [Glass, Saggi, 1999; Smeets, 2008; Branstetter, 2006; Garcia et al., 2024].

Therefore, from a theoretical perspective, hosting FDI should have a positive impact on investment activity, including in R&D, in the host country.

Foreign direct investment, particularly that directly focused on R&D activities (e.g. laboratory work), has a positive impact on the development of the host economy and on domestic R&D activity, as demonstrated by Erdal and Göçer [2015] using the example of developing economies. In this case, Pandey, Sergeeva and Aleksandrova [2022] reached similar conclusions, also identifying a positive impact of FDI. Interestingly, increased R&D expenditure resulting from the presence of FDI does not always lead to an increase in the intensity of such activities [Sharma, 2017]. This may result not only from efforts to attract high-tech FDI, but also from attempts to strengthen the host economy's absorptive capacity with regard to the technology and knowledge transferred by foreign companies, which is essential to demonstrate the impact of FDI on the host country's innovation capacity [Chen, Chen, 2009]. The direction and impact of FDI on R&D – and consequently on innovation capacity – in the host economy may also depend on the form of FDI. For example, in the case of mergers and acquisitions by foreign entities, average R&D expenditure, along with the tendency of companies to engage in innovative activities, shows a downward trend [Stiebale, Reize, 2011]. Azman-Saini, Farhan, Tee and Tun [2018] reached similar conclusions, emphasising that foreign R&D may crowd out its domestic counterpart. This suggests that companies in developing economies tend to imitate rather than innovate. This phenomenon may result from the potentially low importance attributed to the R&D sector – especially in economies that compete with low cost – and, consequently, to the limited capacity to leverage foreign investment in this area [Sanna-Randaccio, 2002]. FDI may also have no impact on R&D in developed countries, which possess sufficient resources to fund such activities independently [Özaytürk, 2025]. Findings suggesting a positive impact of foreign direct investment on R&D and innovation in the host country are consistent with Romer's growth theory [1990] with an increasing number of goods. However, in the case of substitution of domestic activity in this area, Aghion and Howitt's [1992] theory, which is based on the phenomenon of creative destruction [Schumpeter, 1942; see also, e.g., Radło, Szczech-Pietkiewicz, Napiórkowski, 2020], appears more applicable.

In contrast to the aforementioned endogenous theories, empirical research does not provide clear conclusions on the relationship between hosting FDI and R&D. To maximise the benefits of investment in R&D, relevant stakeholders (e.g. lawmakers) should not only focus on attracting high-tech FDI, but also take measures to create incentives for [Nguyen, Sun, Welters, 2024]:

1) direct or indirect technology sharing (spillovers),
2) preventing the crowding out of domestic investment,
3) increasing the absorption capacity,
4) sharing knowledge within local business communities.

In light of the considerations presented above, the aim of this chapter is to test the hypothesis that there is a statistically significant, positive relationship between the activity of foreign investors in host countries and the level of R&D expenditure (both domestic and foreign) in the business enterprise sector in the Visegrád Group countries. The activity of foreign investors is expressed in terms of FDI inflows (IFDI-F) and FDI stock (IFDI-S), while R&D expenditure is broken down according to its source.[1] Foreign direct investment, in turn, should be understood as "an investment… reflecting a lasting interest and control by a resident entity in one economy (foreign direct investor or parent enterprise) in an enterprise resident in an economy other than that of the foreign direct investor (FDI enterprise or affiliate enterprise or foreign affiliate)" [UNCTAD, 2023].

The remainder of this study is devoted to analysing existing data on FDI (Section 2.2), investment in R&D (Section 2.3), and the links between these two areas, together with conclusions that may be drawn from this analysis (Section 2.4).

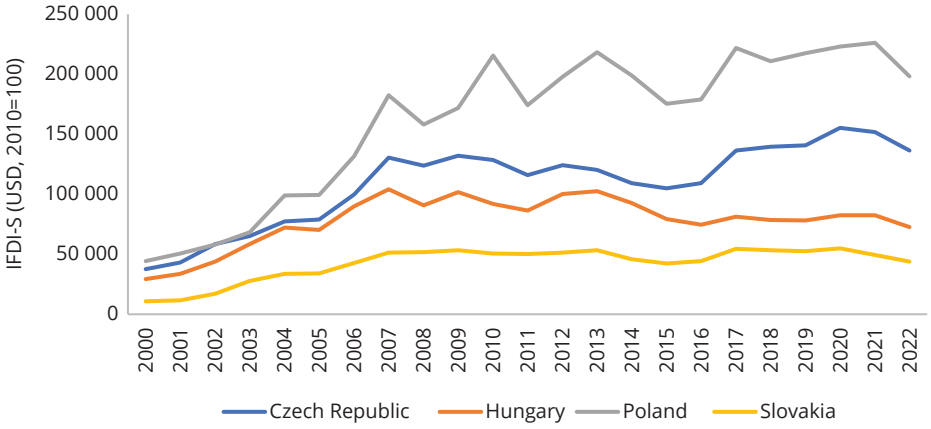
2.2. Foreign direct investment in the Visegrád Group countries

Between 2000 and 2022, the value of FDI stock in each of the Visegrád Group countries (Czech Republic, Hungary, Poland, Slovakia) followed an upward trend. This indicates that the economies under analysis became increasingly attractive to foreign investors during this period (Figure 2.1), with the exception of 2022, which was affected, *inter alia,* by the outbreak of the war in Ukraine. On an annual average basis, FDI stock grew most rapidly in Poland (by USD 7,964.1 million) and most slowly in Hungary (by an average of USD 1,401.1 million).

Unfortunately, this interpretation can be misleading. According to the data presented in Figure 2.2, each of the countries analysed exhibited increasing relative attractiveness (compared with other economies worldwide) until around 2008, when the global financial crisis occurred. In the case of Poland, for example, its peak investment attractiveness was in 2010, when the economy hosted 1.03% of global FDI stock. Since the aforementioned crisis, all four countries under analysis have been losing their relative attractiveness from the perspective of foreign investors.

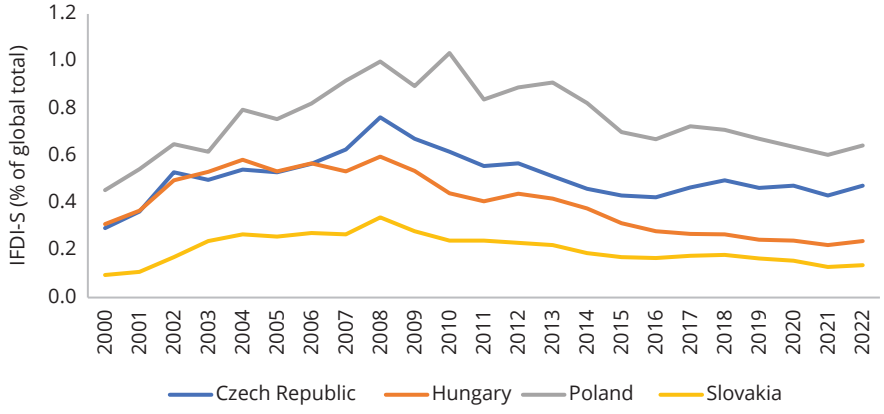
[1] R&D expenditure can be analysed by sector: the business sector as a whole (BERD-Total), businesses (BERD-Bus), government (BERD-Gov), higher education (BERD-Hed) and the private non-profit sector (BERD-Priv).

Figure 2.1. FDI stock in the Visegrád Group countries between 2000 and 2022 (USD, constant prices, 2010 = 100)



Source: own elaboration based on data from the World Bank [2025] and UNCTAD [2025].

Figure 2.2. FDI stock in the Visegrád Group countries between 2000 and 2022 (% of global FDI stock)



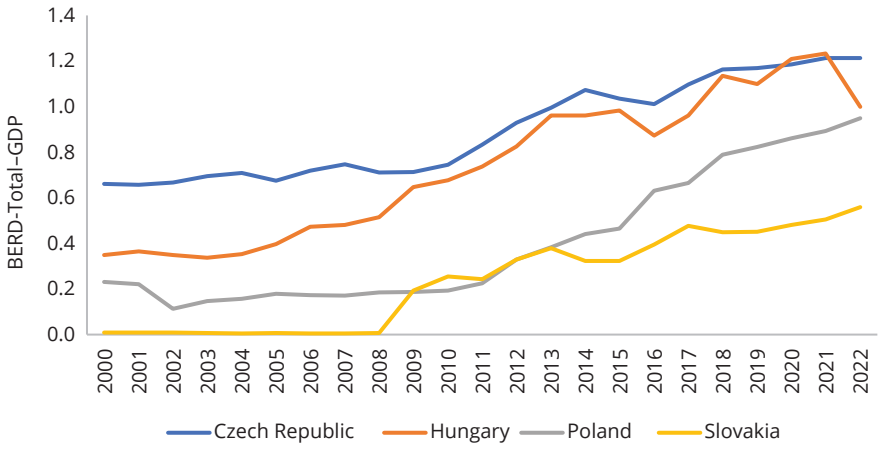
Source: own elaboration based on data from UNCTAD [2025].

Whilst Poland and the Czech Republic saw significant rebounds in relative attractiveness in 2022, factors such as rising energy costs [Barteková, Ziesemer, 2019], expensive loans [Alshubiri, 2022], and the war in Ukraine [Popadynets et al., 2023] do not inspire optimism regarding the sustainability of these changes, which is confirmed by the observable declines in the value of the analysed investment stocks.

2.3. Investment in research and development and its dynamics in the Visegrád Group countries

Among the countries analysed, the Czech Republic has almost consistently spent the most (as a percentage of GDP) on R&D in the business enterprise sector (measured by source of funds). Since around 2009, its expenditure trajectory has remained in line with that of Hungary, which has gradually been catching up. Poland and Slovakia are clearly catching up in this area, and in both cases – as with Hungary – the period following the 2008 financial crisis has been characterised by an accelerated increase in relative R&D expenditure (Figure 2.3). It is worth noting the slowdown in the growth rate of the BERD-Total-to-GDP ratio observed in the Czech Republic. Total business enterprise R&D expenditure as a percentage of GDP has grown most rapidly in Poland and Hungary, with an average annual increase of 0.04 percentage points. The Czech Republic and Slovakia rank second in this respect, with an average annual increase of 0.03 percentage points.

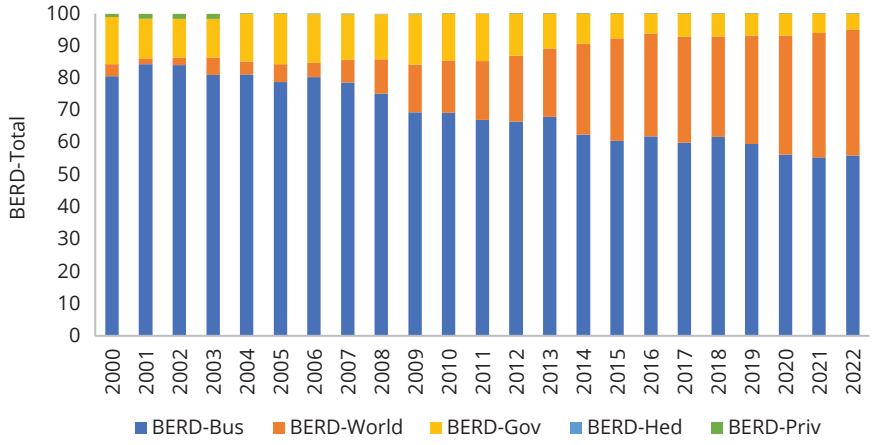
Figure 2.3. R&D expenditure in the Visegrád Group countries between 2000 and 2022 (% of GDP)



Source: own elaboration based on data from UNCTAD [2025].

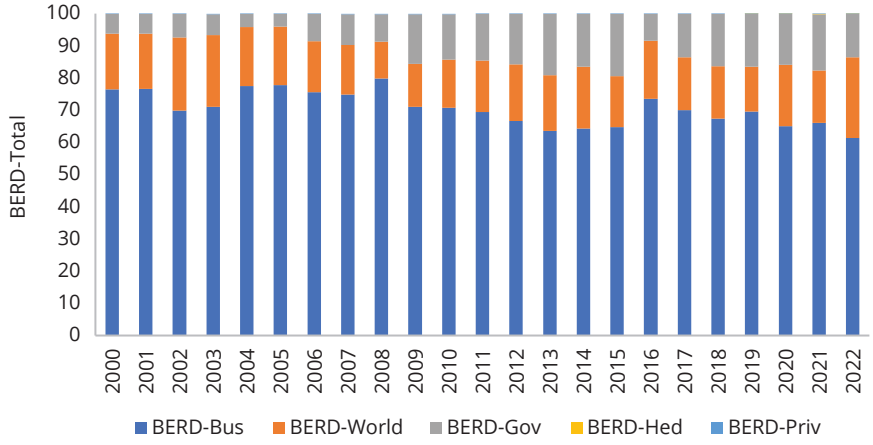
In all the economies analysed, the key source of funding for R&D expenditure in the business enterprise sector is the businesses themselves (BERD-Bus), while higher education (BERD-Hed) and the private non-profit sector (BERD-Priv) invest the least in this area, as demonstrated in Figures 2.4–2.7.

Figure 2.4. Share of funding sources for R&D in the business enterprise sector in the Czech Republic, 2000–2022 (% of total)



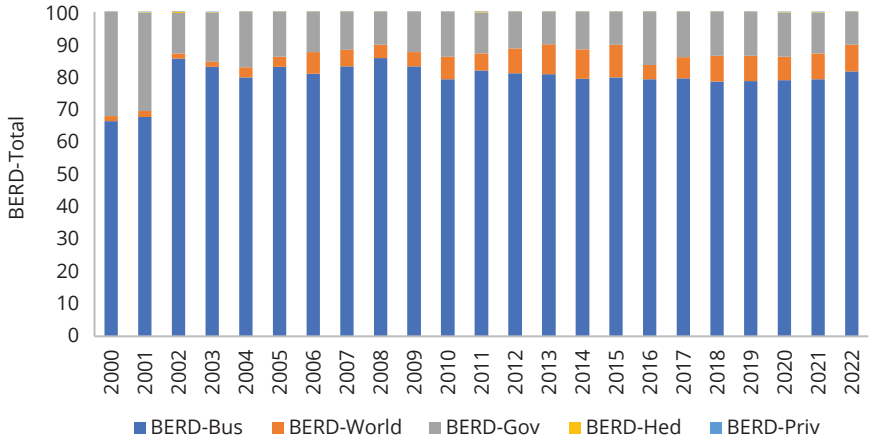
Source: own elaboration based on data from OECD [2025].

Figure 2.5. Share of funding sources for R&D in the business enterprise sector in Hungary, 2000–2022 (% of total)



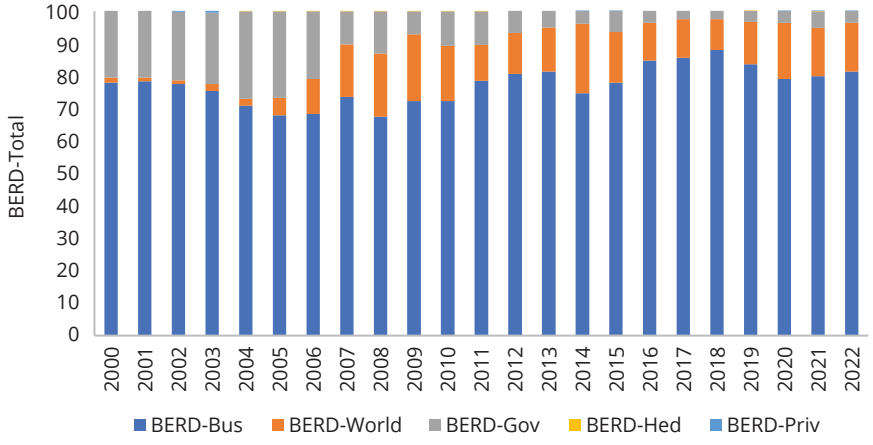
Source: own elaboration based on data from OECD [2025].

Figure 2.6. Share of funding sources for R&D in the business enterprise sector in Poland, 2000–2022 (% of total)



Source: own elaboration based on data from OECD [2025].

Figure 2.7. Share of funding sources for R&D in the business enterprise sector in Slovakia, 2000–2022 (% of total)

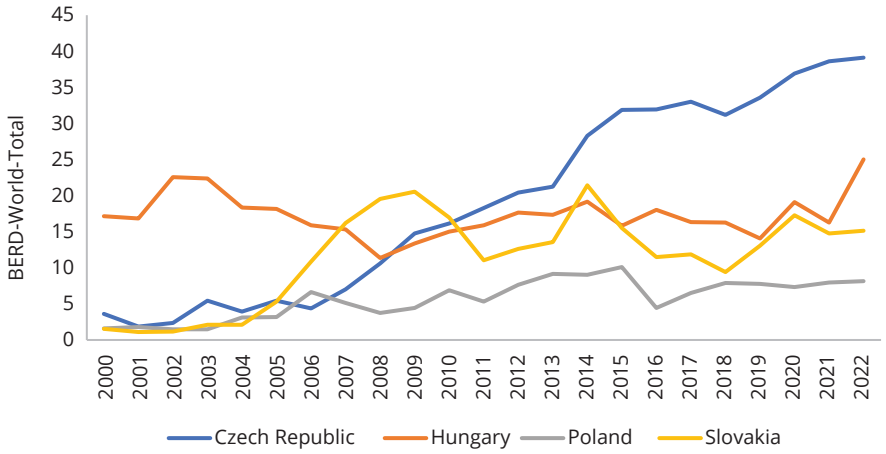


Source: own elaboration based on data from OECD [2025].

Although the share of foreign capital (BERD-World) increased in all of the countries analysed, the Czech Republic also experienced a significant shift from domestic to foreign sources (Figure 2.8). During the period under review, the share of foreign investors in the financing of R&D in the business enterprise sector in Slovakia increased at an average annual rate of 0.019 percentage points. Poland ranked at the

opposite end of this spectrum, both in terms of the importance of foreign capital in the financing of R&D and the rate of growth of this process (0.0032 percentage points on average per year).

Figure 2.8. Share of foreign investors in the financing of R&D in the business enterprise sector in Slovakia, 2000–2022 (% of total)



Source: own elaboration based on data from OECD [2025].

2.4. The relationship between the foreign investment activity and R&D investment in host countries: the case of the Visegrád Group

At the level of the entire Group, positive and statistically significant Pearson correlation coefficients (at the 5% significance level) were identified between both FDI inflows and FDI stock and R&D expenditure, with the exception of investments from the private non-profit sector. However, the results for individual economies were mixed.

In the case of the Czech Republic and Hungary, no statistically significant correlation was observed between FDI inflows and R&D expenditure, either in aggregate terms or broken down by source of funding. Furthermore, FDI inflows are not significantly correlated with selected categories of expenditure, such as BERD-Hed for Poland and Slovakia. The absence of statistically significant correlation coefficients for FDI inflows may be due to the high volatility of FDI inflows compared to FDI stocks and, as is also evident, for example, in the case of the IFDI-S-BERD-Hed pair for Hungary and Slovakia, to the limited involvement of higher education institutions and the private non-profit sector in financing such high-risk activities as R&D.

Table 2.1. Pearson linear correlation coefficients between FDI inflows (IFDI-F) and FDI stock (IFDI-S) and R&D expenditure, broken down by: business sector as a whole (BERD-Total), businesses (BERD-Bus), world (BERD-World), government (BERD-Gov), higher education (BERD-Hed) and the private non-profit sector (BERD-Priv), in the Visegrád Group countries, 2000–2020

		BERD-Total	BERD-Bus	BERD-World	BERD-Gov	BERD-Hed	BERD-Priv
Visegrád Group							
IFDI-F	Pearson correlation	0.505	0.551	0.109	0.497	0.479	0.142
	Significance (two-tailed)	<0.001	<0.001	0.303	<0.001	<0.001	0.178
IFDI-S	Pearson correlation	0.811	0.819	0.454	0.744	0.648	–0.031
	Significance (two-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	0.767
Czech Republic							
IFDI-F	Pearson correlation	–0.195	–0.148	–0.184	–0.201	0.050	0.113
	Significance (two-tailed)	0.373	0.499	0.400	0.358	0.822	0.608
IFDI-S	Pearson correlation	0.917	0.929	0.757	0.486	0.571	–0.727
	Significance (two-tailed)	<0.001	<0.001	<0.001	0.019	0.004	<0.001
Hungary							
IFDI-F	Pearson correlation	–0.019	–0.020	0.038	–0.066	0.522	0.056
	Significance (two-tailed)	0.930	0.928	0.864	0.764	0.367	0.799
IFDI-S	Pearson correlation	0.538	0.565	0.430	0.486	0.155	0.541
	Significance (two-tailed)	0.008	0.005	0.041	0.019	0.804	0.008
Poland							
IFDI-F	Pearson correlation	0.469	0.475	0.460	0.412	0.266	0.479
	Significance (two-tailed)	0.024	0.022	0.027	0.051	0.220	0.021
IFDI-S	Pearson correlation	0.712	0.718	0.724	0.624	0.462	0.466
	Significance (two-tailed)	<0.001	<0.001	<0.001	0.001	0.027	0.025
Slovakia							
IFDI-F	Pearson correlation	–0.667	–0.640	–0.750	–0.615	–0.021	–0.147
	Significance (two-tailed)	<0.001	0.001	<0.001	0.002	0.926	0.503
IFDI-S	Pearson correlation	0.632	0.623	0.608	0.593	0.205	–0.201
	Significance (two-tailed)	0.001	0.001	0.002	0.003	0.348	0.357

Source: own elaboration based on data from UNCTAD [2025] and OECD [2025].

The data collected both for the panel as a whole and for individual economies confirm the existence of very strong, positive, and statistically significant correlations between FDI stock and both total R&D investment and the share of this investment financed by enterprises. This relationship is most pronounced in the Czech Republic

(0.917 and 0.929, respectively), followed by Poland (0.712 and 0.718), Slovakia (0.632 and 0.623) and Hungary (0.538 and 0.565).

To establish causality, the following model was estimated:

$$BERDTotal_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 H_{it} + \beta_3 IFDIS_{it} + \gamma_i + \delta_t + \varepsilon_{it},$$

where total business enterprise R&D expenditure (BERDTotal) is modelled as a function of GDP, human capital (H) and FDI stock (IFDIS); the model also takes into account cross-sectional effects (γ_i), time fixed effects (δ_t), and the error term (ε_{it}).

Data on BERDTotal were taken from the OECD [2025]; for GDP, data were sourced from the World Bank [2025]; human capital values were determined based on data from the University of Groningen [2023; see also: Feenstra, Inklaar, Timmer, 2015], and FDI stock values were taken from UNCTAD [2025]. Given that the data cited were expressed in different units (e.g. US dollars vs national currencies), all variables were converted into USD millions at constant prices, with 2010 as the base year (2010 = 100).

Based on the results of the Hausman test (Prob > chi^2 = 0.0001), a fixed effects model was estimated. The model residuals indicate heteroscedasticity (modified Wald test: Prob > chi^2 = 0.0000) and autocorrelation (Wooldridge test: Prob > F = 0.0028), although they are characterised by a normal distribution (Jarque–Bera test: p-value = 0.1694) and the absence of a unit root (Levin–Lin–Chu test: p-value = 0.0237). Given the correlation of the residuals between cross-sections (Breusch–Pagan test: p-value = 0.0000), the panel-corrected standard error (PCSE) estimator was used [Napiórkowski, 2022].

The model estimated and tested in this way explains 49.84% of the variation in total R&D expenditure, while simultaneously rejecting the null hypothesis that the estimated coefficients are equal to zero (Prob > chi^2 = 0.0000). Both GDP and human capital play a positive and statistically significant role in shaping the investment under analysis (p-value = 0.000 in both cases). The value of the FDI stock coefficient is only 0.004, which, given its p-value of 0.103, suggests that hosting FDI has no, or very limited, impact on total R&D expenditure in the business enterprise sector.

2.5. Conclusions

The aim of this chapter was to test the hypothesis that a positive and statistically significant correlation exists between hosting FDI and the level of R&D expenditure in the business enterprise sector in the Visegrád Group countries. Although from a theoretical perspective, and in light of the concept of economic growth, foreign direct

investment should have a positive impact on R&D, the literature on the subject does not provide unequivocal evidence of this. The studies reviewed suggest that in order for hosted FDI to impact domestic R&D, the host economy must possess sufficient absorptive capacity with regard to the transferred knowledge or be able to make the necessary investments to achieve such absorption.

Within the Visegrád Group, foreign investors account for the largest share of R&D funding in the business enterprise sector in the Czech Republic. Interestingly, while the correlation analysis revealed a relationship between FDI stocks and total R&D expenditure, both from enterprises and from foreign sources, the results of the econometric model indicate that the impact of hosting FDI on total R&D expenditure in the enterprise sector is very limited, if any at all. These findings are consistent with the literature reviewed earlier and suggest that the analysed R&D activity is more likely an indicator of the attraction of foreign partners than a direct result of their presence. In other words, the initial hypothesis of a statistically significant, positive relationship between the activity of foreign investors in host countries and the level of R&D expenditure (both domestic and foreign) in the business enterprise sector in the Visegrád Group countries has not been confirmed.

With regard to Poland itself, it may be concluded that although it is the leading economy among those analysed in terms of attractiveness to foreign investors, it ranks at the bottom in terms of both overall investment in R&D and the attraction of FDI in this area. This suggests that Poland is not yet perceived by foreign investors as an economy with a strong R&D base.

One limitation of this study is the requirement to analyse all four economies included in the panel, resulting from the insufficient length of the available time series for the Visegrád Group. Longer time series would make it possible to single out the Czech Republic and compare the conditions observed there with those present, for example, in Poland.

References

Adams, S. (2009). Foreign Direct Investment, Domestic Investment, and Economic Growth in Sub-Saharan Africa, *Journal of Policy Modeling*, 31(6), pp. 939–949. DOI: 10.1016/j.jpolmod.2009.03.003.

Aghion, P., Howitt, P. (1992). A Model of Growth Through Creative Destruction, *Econometrica*, 60(2), pp. 323–351. DOI: 10.2307/2951599.

Agosin, M.R., Machado, R. (2005). Foreign Investment in Developing Countries: Does It Crowd in Domestic Investment?, *Oxford Development Studies*, 33(2), pp. 149–162. DOI: 10.1080/13600810500137749.

Alshubiri, F. (2022). The Impact of the Real Interest Rate, the Exchange Rate and Political Stability on Foreign Direct Investment Inflows: A Comparative Analysis of G7 and GCC Countries, *Asia-Pacific Financial Markets*, 29, pp. 569–603. DOI: 10.1007/s10690-022-09360-0.

Azman-Saini, W.N.W., Farhan, M.Z.M., Tee, Ch.L., Tun, Y.L. (2018). FDI Inflows and R&D Activity in Developing Countries, *International Journal of Economics and Management*, 12 (S2), pp. 509–521.

Barteková, E., Ziesemer, T.H.W. (2019). The Impact of Electricity Prices on Foreign Direct Investment: Evidence from the European Union, *Applied Economics*, 51(11), pp. 1183–1198. DOI: 10.1080/00036846.2018.1524983.

Boghean, C., State, M. (2015). The Relation Between Foreign Direct Investments (FDI) and Labour Productivity in the European Union Countries, *Procedia Economics and Finance*, 32, pp. 278–285. DOI: 10.1016/S2212-5671(15)01392-1.

Branstetter, L. (2006). Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan's FDI in the United States, *Journal of International Economics*, 68(2), pp. 325–344. DOI: 10.1016/j.jinteco.2005.06.006.

Chen, Y., Chen, J. (2009). The Impact of FDI on Regional Technological Capabilities: Evidence from China, *Journal of Knowledge-Based Innovation in China*, 1(2), pp. 143–158. DOI: 10.1108/17561410910949391.

Erdal, L., Göçer, İ. (2015). The Effects of Foreign Direct Investment on R&D and Innovations: Panel Data Analysis for Developing Asian Countries, *Procedia – Social and Behavioral Sciences*, 195, pp. 749–758. DOI: 10.1016/j.sbspro.2015.06.469.

Feenstra, R.C., Inklaar, R., Timmer, M.P. (2015). The Next Generation of the Penn World Table, *American Economic Review*, 105(10), pp. 3150–3182. DOI: 10.1257/aer.20130954.

Garcia, R., Araujo, V., Mascarini, S., Santos, E.G., Costa, A., Ferreira, S. (2024). Unveiling the Role of Different Types of Local Absorptive Capacity: The Effects of Inward FDI Spillovers on Regional Innovation, *Papers in Regional Science*, 103(5), 100044. DOI: 10.1016/j.pirs.2024.100044.

Glass, A.J., Saggi, K. (1999). Foreign Direct Investment and the Nature of R&D, *The Canadian Journal of Economics*, 32(1), pp. 92–117. DOI: 10.2307/136397.

Ha, V., Holmes, M.J., Tran, T.Q. (2022). Does Foreign Investment Crowd in Domestic Investment? Evidence from Vietnam, *International Economics*, 171, pp. 18–29. DOI: 10.1016/j.inteco.2022.05.003.

Hale, G., Xu, M. (2016). FDI Effects on the Labor Market of Host Countries, *Federal Reserve Bank of San Francisco Working Paper 2016–25*, http://www.frbsf.org/economic- research/publications/working-papers/wp2016-25.pdf (accessed: 19.09.2025).

Liu, W.H. (2016). Intellectual Property Rights, FDI, R&D and Economic Growth: A Cross-Country Empirical Analysis, *The World Economy*, 39(7), pp. 983–1004. DOI: 10.1111/twec.12304.

Lucas, R.E. (1988). On Mechanics of Economic Development, *Journal of Monetary Economics*, 22, pp. 3–42. DOI: 10.1016/0304-3932(88)90168-7.

Miao, M., Borojo, D.G., Yushi, J., Desalegn, T.A. (2021). The Impacts of Chinese FDI on Domestic Investment and Economic Growth for Africa, *Cogent Business and Management*, 8(1), 1886472. DOI: 10.1080/23311975.2021.1886472.

Napiórkowski, T.M. (2017). The Role of Foreign Direct Investment in Economic Growth: The Production Function Perspective, *Optimum*, 5(89), pp. 221–236. DOI: 10.15290/ose.2017.05.89.16.

Napiórkowski, T.M. (2022). *Praktyczna analiza danych za pomocą metod ilościowych*. Warszawa: Oficyna Wydawnicza SGH.

Nguyen, N.M., Sun, S., Welters, R. (2024). The Impact of FDI on R&D Investment of Small and Medium-Sized Enterprises in Vietnam: The Role of Institutions, *International Review of Economics and Finance*, 95, 103519. DOI: 10.1016/j.iref.2024.103519.

OECD (2025). *Business Enterprise R&D Expenditure by Size Class and by Source of Funds*, https://data-explorer.oecd.org/vis?lc=en&df(ds)=DisseminateFinalDMZ&df (id)=DSD_RDS_BERD%40DF_BERD_SOF_SIZE&df(ag)=OECD.STI.STP&df(vs)=1.0&av=true&dq=CZE%2BHUN%2BPOL%2BSVK.A..BES._T%2BBES%2BROW%2BGOV%2BHES%2BPNP.._T…USD_PPP.&pd=%2C&to(TIME_PERIOD)=false&ly(cl)=TIME_PERIOD&ly(rs)=SECT_FUND&vw=tb (accessed: 15.09.2025).

Özaytürk, İ. (2025). Investigation of the Impact of Foreign Direct Investment on Research and Development Spending in the EU Countries, *International Journal of Management Economics and Business*, 21(2), pp. 610–624. DOI: 10.17130/ijmeb.1571133.

Pandey, M.K., Sergeeva, I., Aleksandrova, A. (2022). The Impact of Foreign Direct Investment (FDI) Inflow and Patent Applications on R&D Expenditure in the Context of Innovation Activities: An Empirical Evidence from BRICS Countries Employing Panel VECM Approach, *SPBPU IDE '21: Proceedings of the 3rd International Scientific Conference on Innovations in Digital Economy*, pp. 42–55. DOI: 10.1145/3527049.3527099.

Perić, M., Stanišić, N. (2020). FDI Inflow Effect on Western Balkan Area's Labour Market, *The European Journal of Applied Economics*, 17(2), pp. 147–160. DOI:10.5937/EJAE17-25663.

Popadynets, N., Polishchuk, O., Bilyk, R., Peretiatko, L., Yakymchuk, A., Zapukhlyak, V., Zastavnyy, A., Turala, M. (2023). The Review of Trends and Foreign Direct Investment Estimates in Ukraine and Poland, *Management Theory and Studies for Rural Business and Infrastructure Development*, 46(2), pp. 166–182. DOI: 10.15544/mts.2023.17.

Radło, M.J., Szczech-Pietkiewicz, E., Napiórkowski, T.M. (2020). *Dobrobyt, wzrost gospodarczy i ich nierównomierność w regionie. Wybrane modele, mechanizmy i orientacje polityki rozwojowej*. Warszawa: Oficyna Wydawnicza SGH.

Romer, P.M. (1990). Endogenous Technological Change, *Journal of Political Economy*, 98 (5/2), pp. 71–102, https://www.jstor.org/stable/2937632 (accessed: 15.09.2025).

Sanna-Randaccio, F. (2002). The Impact of Foreign Direct Investment on Home and Host Countries with Endogenous R&D, *Review of International Economics*, 10(2), pp. 278–298. DOI: 10.1111/1467-9396.00332.

Sharma, R. (2017). FDI and Incumbent R&D Behavior: Evidence from Indian Manufacturing Sector, *Journal of Economic Studies*, 44(3), pp. 380–399. DOI: 10.1108/JES-10-2015-0188.

Schumpeter, J.A. (1942). *Capitalism, Socialism and Democracy*. New York: Harper.

Smeets, R. (2008). Collecting the Pieces of the FDI Knowledge Spillovers Puzzle, *World Bank Research Observer*, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2442966 (accessed: 15.09.2025).

Stiebale, J., Reize, F. (2011). The Impact of FDI Through Mergers and Acquisitions on Innovation in Target Firms, *International Journal of Industrial Organization*, 29(2), pp. 155–167. DOI: 10.1016/j.ijindorg.2010.06.003.

Sucubasi, B., Trenovski, B., Imeri, B., Merdzan, G. (2021). The Effects of FDI on Domestic Investments in Western Balkans, *SHS Web of Conferences*, 92(2). DOI: 10.1051/shsconf/20219207059.

Tang, S., Selvanathan, E.A., Selvanathan, S. (2008). Foreign Direct Investment, Domestic Investment and Economic Growth in China: A Time Series Analysis, *The World Economy*, 31(10), pp. 1292–1309. DOI: 10.1111/j.1467–9701.2008.01129.x.

UNCTAD (2023). *World Investment Report 2023: Investing in Sustainable Energy for All*, https://unctad.org/system/files/official-document/wir2023_en.pdf (accessed: 15.09.2025).

UNCTAD (2025). *Foreign Direct Investment: Inward and Outward Flows and Stock, Annual*, https://unctadstat.unctad.org/datacentre/dataviewer/US.FdiFlowsStock (accessed: 15.09.2025).

University of Groningen (2023). *Penn World Table Version 10.01*, https://www.rug.nl/ggdc/productivity/pwt/?lang=en (accessed: 15.09.2025).

World Bank (2025). *World Development Indicators*, https://databank.worldbank.org/source/world-development-indicators (accessed: 15.09.2025).

Chapter 3

The Impact of Research and Development Activities and Innovation on Poland's Competitiveness in Foreign Trade

Artur Franciszek Tomeczek

3.1. Introduction

Research and development (R&D), along with the associated economic innovation, play a crucial role in shaping a country's competitiveness in foreign trade. Inevitably, Poland's economic development is becoming increasingly dependent on the continued advancement of modern technologies. To date, the Polish economy has built its position within the European Union primarily on the basis of a low-cost labour force and strong economic ties with Germany. Rising wages and increasing costs of other production factors in Poland, combined with the revolutionary changes taking place in the global economy, necessitate the adaptation of economic policy to new realities.

Poland's position in international innovation rankings [European Commission, 2025b; WIPO, 2025b] and higher education rankings [ShanghaiRanking, 2025; THE, 2025] falls well below expectations and does not reflect the country's true potential. In Poland, a number of government initiatives are in place to support technological development – to date, a total of 13 National Smart Specialisations (KIS) and 14 Special Economic Zones (SSE) have been launched [Ministry of Economic Development and Technology, 2025a, 2025b]. Funding for Polish science is provided primarily through government agencies, such as the National Science Centre [NCN, 2025] and the National Centre for Research and Development [NCBR, 2025a].

The aim of this chapter is to examine the impact of R&D and innovation on Poland's competitiveness in international trade. The structure of this chapter is aligned with its research objective and comprises five main sections: a review of recent economic publications on R&D, a discussion of the Draghi Report, a comparison of the level of innovation and human capital in Poland, an analysis of statistics on patent applications in Poland, and an explication of statistics on Poland's trade profile.

3.2. The importance of research and development in the economic literature

In the context of international economic cooperation, innovation, productivity and competitiveness constitute a triad of key concepts [Gorynia, 2018]. The economic literature emphasises that R&D exerts a positive impact on the volume of international trade. The number of patents, frequently used to measure the scale of R&D, is directly correlated with export value [Asna Ashari, Blind, 2024; Bierut, Dybka, 2021]. Patents enable multinational corporations to enhance their competitiveness in international markets [Chuang, Tsai, Chang, Wang, 2021]. An increase in production innovativeness significantly enhances the competitiveness of goods exports while reducing the likelihood of its future decline [Xu, Zhan, 2023]. Expenditure on R&D contributes to increasing both the innovativeness and competitiveness of the economy [Peñasco, Anadón, Verdolini, 2021]. It also affects the structure of exports, strengthening the importance of sectors based on advanced technologies [Bierut, Dybka, 2021], and shapes the competitiveness of individual regions within a country [Yang, Dong, Yang, 2024].

Sustained growth in innovativeness requires the presence of several enabling factors. Boikova, Zeverte-Rivza, P. Rivza and B. Rivza [2021] identify macroeconomic stability, R&D and digitalisation, foreign direct investment, and free trade among the most important factors contributing to the competitiveness and economic growth of EU countries. Y. Wang, T. Wang and Q. Wang [2024] likewise highlight the positive impact of digitalisation on the performance of companies exporting goods. Gomez Sanchez, Sarmiento-Castillo and Fajardo-Hoyos [2022] discuss the benefits of acquiring new technologies through R&D expenditure and international trade. A partially contrasting view is presented by Drapkin, Gainetdinova and Panzabekova [2021], who argue that the exports of high-tech goods in Central and Eastern Europe are linked to free trade, high wages, low taxes and the quality of human capital, rather than to R&D expenditure.

From an industry perspective, an economy's innovation may focus on specific sectors or on specialisation within particular links of global value chains. Drelich-Skulska and Bobowski [2021] highlight the potential of trade liberalisation in stimulating intra-industry trade in the automotive sector between the EU and Japan. Using the example of the Swiss medical industry, Vlckova and Thakur-Weigold [2020] demonstrate how highly developed economies specialise in selected links of global value chains associated with R&D activities. According to the model presented by Eid, Mrabet and Alsamara [2024], R&D expenditure on renewable energy sources exerts a stronger positive

impact on energy productivity than R&D expenditure on fossil fuels. As Zhao, Li and Zhang [2024] point out, government subsidies for research and development have a positive impact on the innovativeness of Chinese electric vehicle manufacturers. However, a study by Zhang [2021] leads to a different conclusion, demonstrating that Chinese companies in the high-tech sector are more innovative as a result of investment in innovation and foreign investment, while government support programmes may negatively impact companies' innovativeness.

3.3. Draghi's Report

R&D has been identified as a strategically important area at the European level. In 2024, a document entitled *The Future of European Competitiveness*, more widely known as the Draghi Report, was published [European Commission, 2024]. Part A of the report outlines the overall strategy for Europe's competitiveness [European Commission, 2025c], while Part B focuses on technical analysis and recommendations [European Commission, 2025d].

The Draghi Report emphasises the need to identify new avenues for the development of the European economy in order to address the innovation gap between EU countries and global leaders [European Commission, 2025c, pp. 23–27]. According to the report, without such changes it will be impossible to strengthen European security and make Europe self-sufficient vis-à-vis other economies [European Commission, 2025c, p. 54]. The issue of dependence within EU economies became particularly evident during the recent crises of the COVID-19 pandemic and the war in Ukraine. The former clearly demonstrated the importance of shortening supply chains and the risks associated with European companies relying on production located in distant parts of the world, such as China. Industries of particular strategic importance, such as the pharmaceutical industry, should not rely solely on production carried out in countries like India. The latter crisis – Russia's invasion of Ukraine – demonstrated, particularly in the case of the German economy, the risks associated with dependence on gas supplies from a single non-EU country, namely Russia.

According to the Draghi Report, the transformation of the European economy, together with the need to secure sufficient funds for its proper financing, should primarily focus on areas such as the energy sector, rare-earth resources, digitalisation and advanced technologies, high-speed internet infrastructure, the development of artificial intelligence and semiconductors, energy-intensive industries, clean technologies, the automotive and defence industries, space technologies, the pharmaceutical sector, and transport. The foremost priority listed in the report is

to enhance the innovativeness of the economy [European Commission, 2025d, p. 228]. The main challenges facing Polish industry include very high energy prices and the highest taxes and levies on electricity in the EU [European Commission, 2025d, pp. 6, 19]. A potential long-term solution to this problem is the development of the nuclear energy sector in Poland.

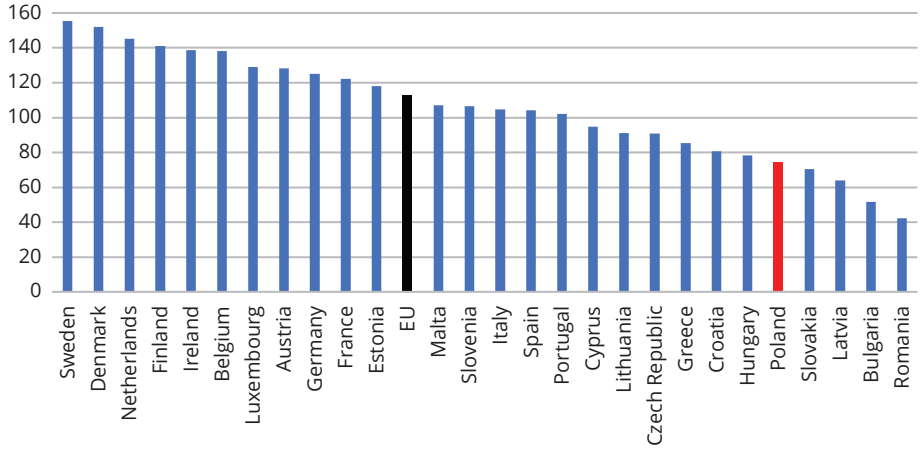
The primary legal act governing research and development issues in Poland is the Act – Law on Higher Education and Science [Journal of Laws 2018, item 1668]. For practitioners, the most detailed source of additional knowledge in this area is *the Frascati Manual* [OECD, 2018]. From the perspective of entrepreneurs, the IP Box (Innovation Box) tax incentive package, promoted by the Coalition for Polish Innovations and the Patent Office of the Republic of Poland, is also of considerable importance [Ministry of Finance, 2019; UPRP, 2019].

In Poland, the primary institution responsible for supporting, promoting and financing R&D is the National Centre for Research and Development (NCBR), an executive agency supervised by the Minister of Science and Higher Education. The NCBR's programmes are aimed at both businesses and academic institutions. Its mission is to "create a world of innovation, building a modern present and future" [NCBR, 2019]. One example of the NCBR's activities aligned with the guidelines set out in the Draghi Report is the STEP initiative, which provides funding under two separate pathways: Option A enables the submission of R&D projects in the field of clean and resource-efficient technologies, while Option B covers applications in the field of digital technologies and innovations combined with the development of deep technologies [NCBR, 2025b–c]. The STEP initiative operates within the framework of the European Funds for Smart Economy programme.

3.4. Innovation and human capital in Poland

In the European Innovation Scoreboard 2025 ranking, Poland, with a score of 74.2, ranked 23rd out of 27 countries and was classified, along with Hungary, Slovakia, Latvia, Bulgaria and Romania, as an "emerging innovator", i.e. among the least innovative economies in the European Union [European Commission, 2025a–b]. Data for all classified economies are presented in Figure 3.1. The most innovative – Sweden (155.5), Denmark (152), the Netherlands (145.3) and Finland (141.1) – form the group of so-called innovation leaders. Poland's score remains well below the EU average, although, on a positive note, it did record the second-highest increase in innovation (from 56.1 to 74.2) in the entire ranking. The largest increase over this period (from 61.2 to 80.6) was recorded by Croatia [European Commission, 2025b, p. 29].

Figure 3.1. European Innovation Scoreboard 2025 ranking



Source: European Commission [2025a].

Table 3.1. Poland's position in the Global Innovation Index 2025 ranking, broken down by individual categories

Index pillars	Rank
Institutions	68
Human capital and research	43
Infrastructure	51
Market sophistication	64
Business sophistication	32
Knowledge- and technology-based outputs	42
Creative outputs	33
Total	39

Source: WIPO [2025a].

In the Global Innovation Index 2025, Poland scored 37.7 points, ranking 39th globally and 25th regionally [WIPO, 2025a]. Although these results are not exactly satisfactory, it is necessary to examine the details of the calculated index to identify the strengths and weaknesses of innovation in the Polish economy. Table 3.1 presents a breakdown of Poland's innovation performance across the individual components of the Global Innovation Index 2025. The highest scores were recorded in the categories of business sophistication – which includes, *inter alia*, knowledge-based work – and creative outputs. By contrast, the lowest scores were observed for institutions and market sophistication, which includes, *inter alia*, access to capital. This suggests

that the innovativeness of Polish manufacturing performs relatively well, given the relatively weak institutional support and limited access to enterprise funding, while at the same time worse than might be expected given Poland's position as one of the world's 20 largest economies.

Table 3.2. Performance of universities from Visegrád Group countries in the Times Higher Education 2026 ranking

Rank	Country	University	Overall	Teaching	Research environment	Research quality	Industry	International outlook
251–300	Hungary	Semmelweis University	54.3–56.3	45.4	28.8	83.5	75.1	76.5
401–500	Czech Republic	Charles University	46.2–49.8	37.9	32.2	64.8	63.4	64.7
501–600	Poland	Jagiellonian University	43.6–46.1	43.8	33.6	51.1	54.2	45.7
501–600	Poland	Wroclaw Medical University	43.6–46.1	43.5	17.9	76.5	48.1	37.5
601–800	Czech Republic	Czech University of Life Sciences Prague	39.0–43.5	25.1	17.5	64.9	47.3	78.5
601–800	Czech Republic	Masaryk University	39.0–43.5	26.8	32.6	57.1	51.1	66.2
601–800	Hungary	Óbuda University	39.0–43.5	17.4	30.9	72.8	27.2	48.8
601–800	Poland	University of Warsaw	39.0–43.5	38.1	32.6	46.7	39.3	45.0
801–1000	Hungary	Eötvös Loránd University	35.5–38.9	29.6	19.8	55.4	39.7	50.3
801–1000	Poland	Medical University of Lodz	35.5–38.9	31.3	11.6	65.5	46.4	31.1
801–1000	Hungary	University of Debrecen	35.5–38.9	41.7	18.2	45.7	50.6	58.0
1201–1500	Slovakia	Comenius University Bratislava	27.3–32.0	29.4	17.0	37.2	30.0	52.9
1201–1500	Slovakia	Pavol Jozef Šafárik University in Košice	27.3–32.0	41.7	11.2	24.5	24.7	59.3
1201–1500	Slovakia	Slovak University of Agriculture in Nitra	27.3–32.0	27.5	19.3	34.0	22.9	49.2
1201–1500	Slovakia	University of Žilina	27.3–32.0	26.2	19.6	39.9	45.5	33.9

Source: THE [2025].

Polish universities do not occupy leading positions in global academic rankings either [ShanghaiRanking, 2025; THE, 2025]. The highest-ranked universities from Poland in the *World University Rankings 2026* compiled by Times Higher Education were the Jagiellonian University and the Wroclaw Medical University, both placed in the 501–600 ranking band. By contrast, in the *Academic Ranking of World Universities 2025* compiled by ShanghaiRanking Consultancy, the University of Warsaw was ranked highest, ranking within the 401–500 band. Table 3.2 presents the eleven

highest-ranked universities from the Visegrád Group countries, and the four highest-ranked Slovak universities. The highest-ranked Polish university ranks below those highest-ranked from Hungary (Semmelweis University) and the Czech Republic (Charles University), but significantly above those from Slovakia. Overall, the position of universities from the entire Visegrád Group does not fully correspond to expectations, and their performance in academic rankings is certainly worse than that of universities in Germany or France.

3.5. Patent applications in Poland

According to a search of the PATENTSCOPE database [WIPO, 2025c], more than 375,000 patent applications were filed in Poland over the entire period for which data is available (1978–2025), including 7,151 submitted under the Patent Cooperation Treaty (PCT). The first three patent applications in Poland available in the database date back to 1978, while the highest number of applications was recorded in 2017 (18,439). In 2024, 16,287 applications were filed, with the number increased by a further 11,852 applications in 2025 (the search was conducted in November 2025). Table 3.3 lists the 40 institutions and companies with the highest number of patent applications in Poland over the entire period covered by the database. Technical universities clearly dominated in terms of the number of patent applications. The most active institutions and companies were the Wroclaw University of Science and Technology (3,137), Warsaw University of Technology (2,459), Silesian University of Technology (1,973), Lublin University of Technology (1,970) and Lodz University of Technology (1,817). The highest-ranked companies included: BASF (894), Unilever (695) and Bayer (663). The list of entities that file the most patent applications in Poland consists primarily of Polish universities, followed by foreign companies, which suggests the need to strengthen the position of Polish enterprises in this area.

Table 3.3. Patent applications in Poland, 1978–2025

Filing institution/company	Patent applications	Filing institution/company	Patent applications
Wroclaw University of Science and Technology	3,137	The Procter & Gamble Company	530
Warsaw University of Technology	2,459	University of Warmia and Mazury in Olsztyn	505
Silesian University of Technology	1,973	The Tele and Radio Research Institute	499
Lublin University of Technology	1,970	Industrial Research Institute for Automation and Measurements (PIAP)	487

cont. Table 3.3

Filing institution/company	Patent applications	Filing institution/company	Patent applications
Lodz University of Technology	1,817	University of Lodz	486
Poznan University of Technology	1,462	Institute of Heavy Organic Synthesis *Blachownia*	480
West Pomeranian University of Technology in Szczecin	1,381	Professor Ignacy Mościcki Industrial Chemistry Institute	443
Gdansk University of Technology	1,191	University of Silesia in Katowice	439
AGH University of Krakow	1,189	AstraZeneca AB	429
Wroclaw University of Environmental and Life Sciences	1,119	Pfizer Inc.	411
Ignacy Łukasiewicz Rzeszow University of Technology	898	L'Oréal	408
BASF AG	894	Bialystok University of Technology	389
AGH University	801	Pfizer Products Inc.	387
Cracow University of Technology	752	KOMAG Institute of Mining Technology	386
Unilever NV	695	Institute for Sustainable Technologies – National Research Institute	385
Central Mining Institute	668	Medical University of Lublin	377
Bayer AG	663	Institute of Non-Ferrous Metals	372
Kielce University of Technology	581	Merck Patent GmbH	372
Novartis AG	572	Eli Lilly and Company	366
Czestochowa University of Technology	552	Institute of Electron Technology	361

Source: WIPO [2025c].

3.6. Poland's trade profile

The revealed comparative advantage (RCA) index for country i and product j is defined as:

$$RCA_{ij} = \left(x_{ij} / X_{it} \right) \left(x_{wj} / X_{wt} \right),$$

where x_{ij} denotes exports of product j by the country, X_{it} represents the total exports of that country, x_{wj} denotes the global exports of product j, and X_{wt} represents total global exports [UNCTAD, 2025a–b; WITS, 2025a–b].

Country i has an above-average comparative advantage in exporting product j if the RCA is greater than 1. The higher the RCA value, the greater the comparative advantage associated with the product.

Table 3.4 presents Poland's export profile from the perspective of the 30 products with the highest RCA values in 2024. UNCTAD statistics are based on the product

categories of the *Standard International Trade Classification Revision 3* – SITC Rev. 3. The strongest comparative advantage in Poland's exports was observed for coke and semi-coke of coal (SITC – 325, RCA – 13.2), dried and smoked fish (SITC – 035, RCA – 11.1), and manufactured tobacco (SITC – 122, RCA – 8.2). Other products that recorded a significant annual increase in comparative advantage included coins other than gold coins (SITC – 961, 305%), arms and ammunition (SITC – 891, 64.3%), and railway vehicles (SITC – 791, 12.5%).

Table 3.4. Products with the highest RCA in Polish exports

SITC code	Category	RCA 2023	RCA 2024	Change (%)
325	Coke and semi-coke of coal, lignite. peat; retort carbon	14.8	13.2	–10.8
035	Fish, dried, salted or in brine; smoked fish	9.9	11.1	12.1
122	Tobacco, manufactured	8.5	8.2	–3.5
961	Coin (other than gold coin), not being legal tender	2.0	8.1	305.0
635	Wood manufactures, n.e.s.	5.9	5.9	0.0
017	Meat, edible meat offal, prepared, preserved, n.e.s.	5.2	5.6	7.7
677	Rails & railway track construction materials, iron, steel	5.5	5.4	–1.8
025	Birds' eggs, and eggs' yolks; egg albumin	4.8	4.7	–2.1
073	Chocolate, food preparations with cocoa, n.e.s.	4.3	4.6	7.0
696	Cutlery	4.6	4.6	0.0
891	Arms & ammunition	2.8	4.6	64.3
821	Furniture & parts thereof	4.5	4.4	–2.2
045	Cereals, unmilled (excluding wheat, rice, barley, maize)	4.6	4.2	–8.7
012	Other meat and edible meat offal	3.7	4.0	8.1
761	Television receivers, whether or not combined	3.9	3.9	0.0
583	Monofilaments, of plastics, cross-section > 1 mm	4.0	3.8	–5.0
691	Structures & parts thereof, n.e.s., of iron, steel, aluminium	3.6	3.6	0.0
791	Railway vehicles & associated equipment	3.2	3.6	12.5
212	Raw furskins other than hides & skins of group 211	3.8	3.5	–7.9
642	Paper & paperboard, cut to shape or size, articles	3.2	3.3	3.1
775	Household type equipment, electrical or non-electrical, n.e.s.	3.4	3.3	–2.9
629	Articles of rubber, n.e.s.	3.3	3.2	–3.0
048	Cereal preparations, flour of fruits or vegetables	2.9	3.0	3.4
245	Fuel wood (excluding wood waste) and wood charcoal	3.0	2.9	–3.3
554	Soaps, cleansing and polishing preparations	2.9	2.9	0.0
663	Mineral manufactures, n.e.s.	2.9	2.9	0.0
892	Printed matter	3.0	2.9	–3.3

cont. Table 3.4

SITC code	Category	RCA 2023	RCA 2024	Change (%)
783	Road motor vehicles, n.e.s.	3.6	2.8	–22.2
621	Rubber materials (pastes, plates, sheets, etc.)	2.7	2.7	0.0
664	Glass	2.6	2.7	3.8

Source: UNCTAD [2025b].

Table 3.5. Poland's exports of goods in 2024 (USD thousand)

HS code	Product	Value of exports
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	50,439,756
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers; and parts and accessories of such articles	43,978,140
87	Vehicles other than railway or tramway rolling stock, and parts and accessories thereof	41,164,358
39	Plastics and articles thereof	18,007,592
94	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; luminaires and lighting fittings, not elsewhere specified or included; illuminated signs, illuminated nameplates and the like; prefabricated buildings	17,626,526
73	Articles of iron or steel	11,765,650
27	Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes	9,823,123
02	Meat and edible meat offal	8,858,054
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof	8,302,248
62	Articles of apparel and clothing accessories, not knitted or crocheted	7,637,328
30	Pharmaceutical products	6,972,076
40	Rubber and articles thereof	6,702,960
48	Paper and paperboard; articles of paper pulp, of paper or of paperboard	6,597,670
44	Wood and articles of wood; wood charcoal	6,372,284
61	Articles of apparel and clothing accessories, knitted or crocheted	6,090,245
24	Tobacco and manufactured tobacco substitutes; products, whether or not containing nicotine, intended for inhalation without combustion; other nicotine-containing products intended for the intake of nicotine into the human body	6,033,032
74	Copper and articles thereof	5,841,796
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations	5,772,308
72	Iron and steel	5,759,393
76	Aluminium and articles thereof	5,349,962
Total		380,333,187

Source: ITC [2025].

Table 3.6. Poland's imports of goods in 2024 (USD thousand)

HS code	Product	Value of imports
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	46,797,079
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers; and parts and accessories of such articles	45,390,898
87	Vehicles other than railway or tramway rolling stock, and parts and accessories thereof	40,035,713
27	Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes	28,829,546
39	Plastics and articles thereof	19,306,032
30	Pharmaceutical products	14,270,458
72	Iron and steel	12,177,823
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof	8,477,401
62	Articles of apparel and clothing accessories, not knitted or crocheted	8,295,201
73	Articles of iron or steel	7,984,613
61	Articles of apparel and clothing accessories, knitted or crocheted	7,853,401
48	Paper and paperboard; articles of paper pulp, paper or paperboard	6,471,184
76	Aluminium and articles thereof	6,431,606
99	Commodities not elsewhere specified	5,927,779
40	Rubber and articles thereof	5,431,844
94	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; luminaires and lighting fittings, not elsewhere specified or included; illuminated signs, illuminated nameplates and the like; prefabricated buildings	5,409,328
64	Footwear, gaiters and the like; parts of such articles	4,922,643
38	Miscellaneous chemical products	4,898,061
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations	4,377,547
29	Organic chemicals	4,347,719
Total		379,496,070

Source: ITC [2025].

Tables 3.5 and 3.6 present the value structure of Poland's exports and imports. Official Polish translations of HS codes are available in the ISZTAR4 system [Ministry of Finance, 2025]. Poland's foreign trade is predominantly intra-industry: 16 of the 20 leading products appear on both the list of the most important exports and that of most important imports. The three most significant product groups in both the exports and imports categories are nuclear reactors and parts thereof, etc. (HS 84), electrical machinery and equipment and parts thereof, etc. (HS 85), as well as vehicles other than railway or tramway rolling stock, and parts and accessories thereof (HS 87).

3.7. Conclusions

Poland is a large and rapidly growing economy. However, its position in innovation rankings does not reflect either the expectations placed upon it or its true potential. Expenditure on R&D is of fundamental importance for the innovativeness of economies, although other factors – such as institutional support, the development of science and human capital, foreign investment and free trade – also play an important role. Polish society currently faces both significant opportunities and substantial threats.

The considerable national and EU funds allocated to the development of the defence-related sector will inevitably contribute to technological progress. At the same time, industry in Poland is grappling with very high energy prices and the highest taxes and levies on electricity in the EU. One potential long-term solution to this problem is the development of Poland's nuclear energy sector.

According to the results of the *Global Innovation Index 2025*, the innovativeness of Polish manufacturing has reached a relatively high level given the relatively weak institutional support and limited access to enterprise funding. Nevertheless, it is still insufficient for a country that prides itself on being one of the world's 20 largest economies. In this context, measures aimed at further development of Polish universities – including improving their position in international rankings – as well as strengthening the role of Polish companies in patent activity should be considered essential in this regard. In Poland, patents are filed mainly by universities of technology, which stands in stark contrast to countries such as Germany or the United States, where patents are filed primarily by private companies.

Poland's foreign trade is predominantly intra-industry in nature. The most important categories for both exports and imports are HS 84 (nuclear reactors and parts thereof, etc.), HS 85 (electrical machinery and equipment and parts thereof, etc.) and HS 87 (vehicles other than railway or tramway rolling stock, and parts and accessories thereof). Once again, the strongest comparative advantage in Polish exports was recorded for coke and semi-coke of coal (RCA – 13.2), despite a decrease in the RCA compared to the previous year (–10.8%). Notably, there was also a 64.3% increase in comparative advantage in exports of arms and ammunition, from an RCA of 2.8 to an RCA of 4.6.

References

Act of 20 July 2018 – Law on Higher Education and Science (Journal of Laws 2018, item 1668), https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180001668 (accessed: 15.11.2025).

Asna Ashari, P., Blind, K. (2024). The Effects of Hydrogen Research and Innovation on International Hydrogen Trade, *Energy Policy*, 186, 113974. DOI: 10.1016/j.enpol.2023.113974.

Bierut, B.K., Dybka, P. (2021). Increase versus Transformation of Exports Through Technological and Institutional Innovation: Evidence from Bayesian Model Averaging, *Economic Modelling*, 99, 105501. DOI: 10.1016/j.econmod.2021.105501.

Boikova, T., Zeverte-Rivza, S., Rivza, P., Rivza, B. (2021). The Determinants and Effects of Competitiveness: The Role of Digitalization in the European Economies, *Sustainability*, 13(21), 11689. DOI: 10.3390/su132111689.

Chuang, C.C., Tsai, C.M., Chang, H.C., Wang, Y.H. (2021). Applying Quantile Regression to Assess the Relationship Between R&D, Technology Import and Patent Performance in Taiwan, *Journal of Risk and Financial Management*, 14(8), 358. DOI: 10.3390/jrfm 14080358.

Drapkin, I.M., Gainetdinova, A.A., Panzabekova, A.Z. (2021). Determinants of High-Tech Export in CEE and CIS Countries, *Economy of Region*, 17(2), pp. 486–501. DOI: 10.17059/ekon.reg.2021-2-10.

Drelich-Skulska, B., Bobowski, S. (2021). Intra-Industry Trade and Implications of the European Union – Japan Economic Partnership Agreement from the Perspective of the Automotive Industry, *Entrepreneurial Business and Economics Review*, 9(2), pp. 183–206. DOI: 10.15678/EBER.2021.090212.

Eid, A.G., Mrabet, Z., Alsamara, M. (2024). Assessing the Impact of Energy R&D on Green Growth in OECD Countries: A CS-ARDL Analysis, *Environmental Economics and Policy Studies*. DOI: 10.1007/s10018-024-00413-4.

European Commission (2024). *The Draghi Report on EU Competitiveness*, https://commission.europa.eu/topics/competitiveness/draghi-report_en (accessed: 15.11.2025).

European Commission (2025a). *European Innovation Scoreboard*, https://projects.research-and-innovation.ec.europa.eu/en/statistics/performance-indicators/european-innovation-scoreboard/eis#/eis (accessed: 16.11.2025).

European Commission (2025b). *European Innovation Scoreboard 2025*. Luxembourg: Publications Office of the European Union. DOI: 10.2777/3239776.

European Commission (2025c). *The Future of European Competitiveness. Part A: A Competitiveness Strategy for Europe*. Luxembourg: Publications Office of the European Union. DOI: 10.2872/1823372.

European Commission (2025d). *The Future of European Competitiveness. Part B: In-Depth Analysis and Recommendations*. Luxembourg: Publications Office of the European Union. DOI: 10.2872/1823372.

Gomez Sanchez, A.M., Sarmiento-Castillo, J.I., Fajardo-Hoyos, C.L. (2022). Regional Business Cycles and Manufacturing Productivity: Empirical Evidence in Colombia, *Economia*, 23(1), pp. 62–87. DOI: 10.1108/ECON-05-2022-0020.

Gorynia, M. (2018). Innowacyjność, produktywność i konkurencyjność gospodarki a międzynarodowa współpraca gospodarcza, *Ruch Prawniczy, Ekonomiczny i Socjologiczny*, 80(4), pp. 209–228. DOI: 10.14746/rpeis.2018.80.4.16.

ITC (2025). *Trade Map Database*, https://www.trademap.org/ (accessed: 17.11.2025).

Ministry of Economic Development and Technology (2025a). *Krajowe Inteligentne Specjalizacje*, https://www.gov.pl/web/rozwoj-technologia/krajowe-inteligentne-specjalizacje (accessed: 29.08.2025).

Ministry of Economic Development and Technology (2025b). *Specjalne Strefy Ekonomiczne*, https://www.gov.pl/web/rozwoj-technologia/specjalne-strefy-ekonomiczne (accessed: 29.08.2025).

Ministry of Finance (2019). *Objaśnienia podatkowe dot. preferencyjnego opodatkowania dochodów wytwarzanych przez prawa własności intelektualnej – IP BOX*, https://www.gov.pl/web/finanse/objasnienia-podatkowe-dot-preferencyjnego-opodatkowania-dochodow-wytwarzanych-przez-prawa-wlasnosci-intelektualnej-ip-box (accessed: 12.11.2025).

Ministry of Finance (2025). *Informacyjny System Zintegrowanej Taryfy Celnej (ISZTAR4)*, https://ext-isztar4.mf.gov.pl/taryfa_celna/Browser?lang=PL (accessed: 17.11.2025).

NCBR (2019). *O nas*, https://www.gov.pl/web/ncbr/ncbr (accessed: 12.11.2025).

NCBR (2025a). [Homepage], https://www.gov.pl/web/ncbr (accessed: 29.08.2025).

NCBR (2025b). *STEP-Ścieżka A: Czyste i zasobooszczędne technologie*, https://www.gov.pl/web/ncbr/step-sciezka-a-czyste-i-zasobooszczedne-technologie (accessed: 12.11.2025).

NCBR (2025c). *STEP-Ścieżka B: Czyste i zasobooszczędne technologie*, https://www.gov.pl/web/ncbr/step-sciezka-b-czyste-i-zasobooszczedne-technologie (accessed: 12.11.2025).

NCN (2025). [Homepage], https://ncn.gov.pl/ (accessed: 29.08.2025).

OECD (2018). *Podręcznik Frascati 2015. Zalecenia dotyczące pozyskiwania i prezentowania danych z zakresu działalności badawczej i rozwojowej: pomiar działalności naukowo-technicznej i innowacyjnej*. Szczecin: Statistics Poland.

Peñasco, C., Anadón, L.D., Verdolini, E. (2021). Systematic Review of the Outcomes and Trade-Offs of Ten Types of Decarbonization Policy Instruments, *Nature Climate Change*, 11(3), pp. 257–265. DOI: 10.1038/s41558-020-00971-x.

ShanghaiRanking (2025). *2025 Academic Ranking of World Universities*, https://www.shanghairanking.com/rankings/arwu/2025 (accessed: 15.11.2025).

THE (2025). *World University Rankings 2026*, https://www.timeshighereducation.com/world-university-rankings/latest/world-ranking (accessed: 05.11.2025).

UNCTAD (2025a). *Revealed Comparative Advantage*, https://unctadstat.unctad.org/EN/RcaRadar.html (accessed: 17.11.2025).

UNCTAD (2025b). *Revealed Comparative Advantage Index, Annual (Analytical)*, https://unctadstat.unctad.org/datacentre/dataviewer/US.RCA (accessed: 17.11.2025).

UPRP (2019). *Zachęcamy do zapoznania się ze zaktualizowaną wersją raportu „Innovation Box / IP BOX. Mechanizm działania w Polsce. Przegląd aktualnych rozwiązań w Europie"*, https://uprp.gov.pl/pl/aktualnosci/informacje/zachecamy-do-zapoznania-sie-ze-zaktualizowana-wersja-raportu-innovation-box-ip-box-mechanizm-dzialania-w-polsce-przeglad-aktualnych-rozwiazan-w-europie (accessed: 12.11.2025).

Vlckova, J., Thakur-Weigold, B.S. (2020). Global Value Chains in the MedTech Industry, *International Journal of Emerging Markets*, 15(1), pp. 70–92. DOI: 10.1108/IJOEM-05-2017-0179.

Wang, Y., Wang, T., Wang, Q. (2024). The Impact of Digital Transformation on Enterprise Performance: An Empirical Analysis Based on China's Manufacturing Export Enterprises, *PLOS ONE*, 19(3), e0299723. DOI: 10.1371/journal.pone.0299723.

WIPO (2025a). *Economy Profile: Poland*, https://www.wipo.int/gii-ranking/en/poland/section/economy-profile (accessed: 05.11.2025).

WIPO (2025b). *Global Innovation Index 2025: Innovation at a Crossroads – Unlocking the Promise of Social Entrepreneurship*. Geneva: World Intellectual Property Organization. DOI: 10.34667/TIND.58864.

WIPO (2025c). *PATENTSCOPE Database*, https://patentscope.wipo.int (accessed: 17.11.2025).

WITS (2025a). *Merchandise Trade Indicator Metadata*, https://wits.worldbank.org/countryprofile/metadata/en/indicator/trade (accessed: 17.11.2025).

WITS (2025b). *Trade Indicators*, https://wits.worldbank.org/wits/wits/witshelp/Content/Utilities/e1.trade_indicators.htm (accessed: 17.11.2025).

Xu, Z.Y., Zhan, M.H. (2023). Technology Innovation and the Duration of Export Competitiveness, *Applied Economics Letters*, 30(10), pp. 1381–1384. DOI: 10.1080/13504851.2022.2056121.

Yang, L., Dong, J., Yang, W. (2024). Analysis of Regional Competitiveness of China's Cross-Border E-commerce, *Sustainability*, 16(3), 1007. DOI: 10.3390/su16031007.

Zhang, Y. (2021). The Regional Disparity of Influencing Factors of Technological Innovation in China: Evidence from High-Tech Industry, *Technological and Economic Development of Economy*, 27(4), pp. 811–832. DOI: 10.3846/tede.2021.14828.

Zhao, Q., Li, Z., Zhang, C. (2024). The Impact of R&D and Non-R&D Subsidies on Technological Innovation in Chinese Electric Vehicle Enterprises, *World Electric Vehicle Journal*, 15(7), 304. DOI: 10.3390/wevj15070304.

Chapter 4

The Technology Intensity of Polish Exports of Goods

Aleksandra Szarek-Piaskowska

4.1. Introduction

The relationship between trade and innovation processes is interdependent. Trade impacts innovation through, *inter alia,* technology diffusion (imports, foreign direct investment, trade in technology), competition, exports, market size, comparative advantage and knowledge externalities [for more information, see: Kiriyama, 2012; Geng, Kali, 2021; Melitz, Redding, 2021; European Investment Bank, 2022]. The literature has also documented the reverse relationship, namely that innovation may determine the export performance of enterprises [e.g. Barrios, Görg, Strobl, 2003; Filipescu, Prashantham, Rialp, Rialp, 2013; Heijs, Valdiviezo, 2013; Nguyen, Pham, Do, Van-Chung, 2025]. A similar, two-way relationship exists between exports of high-tech goods and expenditure on research and development [Yasar, Dayanan, 2024]. The level of R&D expenditure exerts a positive impact on exports of high-tech products [e.g. Braunerhjelm, Thulin, 2008; Chen, Zhang, Lei, Chen, 2023; Saliya, 2025; Sandu, Ciocanel, 2014; Topcu, 2018]. In turn, exports of these types of goods constitute a key driver of economic growth and global competitiveness [Saliya, 2025; Sandu, Ciocanel, 2014], partly due to the high added value they generate [Yasar, Dayanan, 2024]. Consequently, a high share of high-tech exports is regarded as one of the factors determining a country's position in the global economy.

In Poland, during the first decade of the 21st century, the share of medium-tech and high-tech goods in exports increased, although their position did not appear particularly strong [Michalski, 2013]. In the first years of Poland's membership in the European Union (EU), the commodity structure of exports improved, evolving towards mid- and high-tech goods, but this process was very gradual and even came to a halt after 2009, with exports at that time dominated by mid- and low-tech goods [Czarny, Folfas, 2020; Gawlikowska-Hueckel, Śledziewska, 2016].

The aim of this chapter is to determine the level of technology intensity of Polish exports of goods in 2003–2024, i.e. during more than two decades of Poland's membership in the EU. The technology intensity of goods exports depends on their commodity structure, specifically on whether they are dominated by raw materials or by goods manufactured using complex and very rapidly changing technologies that require medium-high and high levels of R&D intensity. The assessment of the technology intensity of Polish exports of goods is intended to answer the following questions:

- How has the technological sophistication of Polish exports of goods evolved during the period of EU membership?
- Which product groups belonging to the categories of medium- and high-technology manufactures constitute Poland's export specialisations?
- In the export of which categories and subcategories of goods has Poland developed lasting, revealed comparative advantages (RCA)?
- What is the position of Polish exports of goods in terms of technology intensity compared with other EU economies?

The methodology adopted in this study is based on a literature review and empirical analyses covering the years 2003–2024, including a comparative analysis of the technology intensity of Polish product exports vis-à-vis the exports of other EU Member States. The data used in the empirical analyses were sourced from the international UNCTAD database [2025]. The analysis of the technological intensity of Polish goods exports was based on the classification proposed by Lall [2000]. Other goods classification systems, such as the Harmonised System (HS), the Standard International Trade Classification (SITC), the Combined Nomenclature (CN), Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE), or the Polish Classification of Goods and Services (PKWiU), encompass a wide range of products and activities but, due to their different purposes, reflect the technological sophistication of products to a limited extent [Czarny, Folfas, Szarek-Piaskowska, 2023]. In comparison with other technological sophistication-oriented classifications of goods, such as those proposed by Hatzichronoglou [1997] or Jaffe and Gordon [1993], Lall's taxonomy appears to be the most comprehensive. Furthermore, it enables a fairly precise grouping of goods in terms of their technology sophistication [Radło, Szarek-Piaskowska, 2022].

Lall identified six main categories of goods based on their factor and technology intensity, drawing on the three-digit SITC (Revision 2). He further divided some of these categories into subcategories, thereby creating the following taxonomy of goods:

- primary products – mainly agricultural products and raw materials that do not require processing, e.g. raw fruit, tea, rice, silk, zinc;

- resource-based manufactures (RB) – agro- and forest-based products, e.g. cheese, honey, sugar, salted fish, paper, cardboard, rubber goods; as well as other resource-based products, e.g., animal oils and fats, iron ore and concentrates, glass; i.e., products manufactured using techniques that involve the intensive use of raw materials while also requiring the use of other inputs, e.g. labour and capital;
- low-technology manufactures (LTM) – textile/fashion cluster, e.g. footwear, leather goods, textile yarn, travel goods, women's clothing; as well as other low-technology manufactures, e.g. furniture, musical instruments, iron or steel wire, ceramics, nails, screws, i.e. products manufactured using standard technologies that are well-known and widely used worldwide;
- medium-technology manufactures (MTM) – automotive products, e.g. motor vehicles for the transport of persons or goods, bicycles, parts and accessories of vehicles; medium-technology process industry products, e.g. perfumes, cosmetics, trailers and semi-trailers, railway vehicles, polymers in primary forms, plastic pipes; and medium-technology engineering industry products, e.g. tractors, internal combustion piston engines, household-type equipment (electrical or otherwise), ships, boats and floating structures, meters, and counters; products manufactured using complex technologies that require the application of advanced skills, prolonged learning, and moderately intensive R&D efforts;
- high-technology manufactures (HTM) – electronics and electrical products, e.g. television receivers, electrical machinery and apparatus, and automatic data processing machines; as well as other high-technology manufactures, e.g. medicinal and pharmaceutical products, medicaments, optical instruments and apparatus, and aircraft, i.e. products manufactured using new and rapidly evolving technologies that require highly intensive R&D efforts;
- other transactions, e.g. works of art, antiques, coins not used as legal tender, and electricity.

Although Lall's classification provides a relatively clear division into individual categories and subcategories of goods, it also has certain limitations. In particular, it does not cover the differentiation of products based on quality or the level of technological complexity. It only reflects the achievements of the final manufacturer, disregarding the use of foreign high-tech intermediate goods in the production of final goods. The classification also excludes services, which constitutes a limitation in the context of global value chains and digitalisation processes, where the distinction between goods and services is becoming increasingly blurred [Czarny et al., 2023].

It was only a dozen or so years ago that the Lall classification was included in UNCTAD's statistical databases, which is why the number of trade-related studies based on it remains relatively limited [see, e.g., Trindade, Pereira de Oliveira, 2017;

Gehl Sampath, Vallejo, 2018; Zapata, Arrazola, de Hevia, 2024]. In studies concerning Poland's foreign trade, the Lall classification was used by Czarny and Folfas [2020] and by Radło and Szarek-Piaskowska [2022].

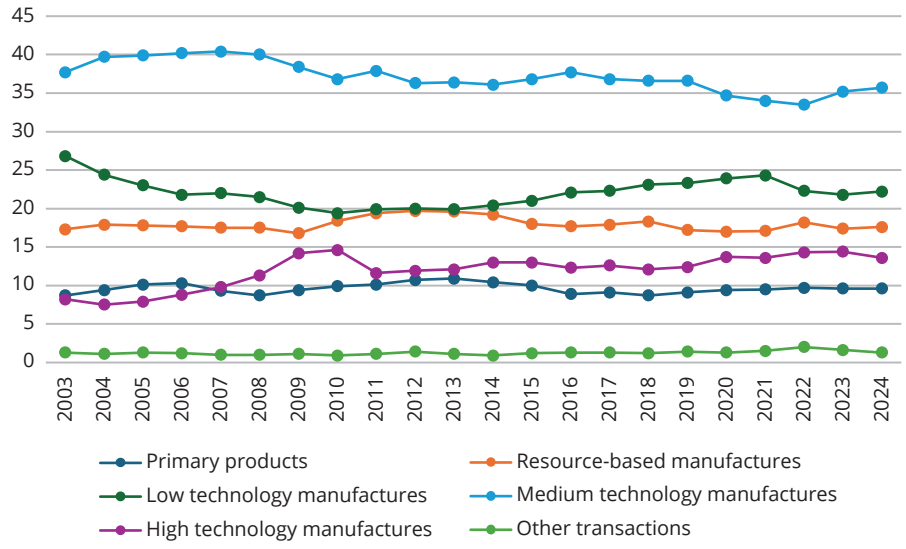
The technology intensity of goods exports is measured by the share of medium- and high-technology manufactures (identified according to the Lall classification) in the overall structure of goods exports. This chapter assumes that the higher the share of medium- and high-technology manufactures in the structure of product exports, the higher the technology intensity of product exports.

The study consists of five parts. Following the introductory remarks, Section 2 examines the structure of Poland's goods exports between 2003 and 2024, with particular emphasis on medium- and high-technology manufactures. The next section analyses the revealed comparative advantages of Poland's exports. Subsequently, the technology intensity of Polish product exports is analysed in comparison with that of other EU Member States. Finally, Section 5 provides a summary of the analyses presented.

4.2. Structure of Polish product exports

The structure of Polish product exports between 2003 and 2024, according to the Lall classification, is presented in Figure 4.1 and Table 4.1.

Figure 4.1. The structure of Polish goods exports between 2003 and 2024 according to the Lall classification (%)



Source: own calculations based on data from UNCTAD [2025].

The share of primary products in exports remained relatively stable over the period under review, at approx. 10%. The range of fluctuation in this indicator did not exceed 2.5 percentage points. The highest share – over 10% of exports – was recorded in the periods 2005–2006 and 2011–2014. In 2024, primary products accounted for 9.6% of Polish exports, i.e. less than one percentage point more than in the first year of the analysis.

Table 4.1. The structure of Polish goods exports between 2003 and 2024 according to the Lall classification (%)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Exports of all products	100	100	100	100	100	100	100	100	100	100	100
Primary products	8.7	9.4	10.1	10.3	9.3	8.7	9.4	9.9	10.1	10.7	10.9
RB: agro- and forest-based products	11.4	11.1	11.3	11.1	11.0	10.7	11.6	11.8	11.9	12.2	12.7
RB: other	5.8	6.8	6.5	6.6	6.5	6.8	5.2	6.6	7.5	7.5	6.9
LTM: textile and fashion cluster	7.1	5.6	4.9	4.1	3.8	3.7	3.9	3.7	3.7	3.6	3.7
LTM: other	19.7	18.8	18.1	17.7	18.2	17.8	16.2	15.7	16.2	16.4	16.2
MTM: automotive products	9.5	12.0	12.4	12.8	12.8	13.7	14.3	12.7	12.2	10.8	10.3
MTM: process industry products	6.8	7.1	7.0	7.2	7.5	8.1	7.0	7.5	8.3	8.3	8.2
MTM: engineering industry products	21.5	20.6	20.5	20.2	20.1	18.2	17.1	16.6	17.4	17.2	17.9
HTM: electronics and electrical products	6.9	6.1	6.5	7.5	8.4	9.6	12.2	12.4	9.6	9.6	9.3
HTM: other	1.3	1.4	1.4	1.3	1.4	1.7	2.0	2.2	2.0	2.3	2.8
Other transactions	1.3	1.1	1.3	1.2	1.0	1.0	1.1	0.9	1.1	1.4	1.1
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Exports of all products	100	100	100	100	100	100	100	100	100	100	100
Primary products	10.4	10.0	8.9	9.1	8.7	9.1	9.4	9.5	9.7	9.6	9.6
RB: agro- and forest-based products	12.6	12.4	12.7	12.9	12.9	12.2	12.6	12.1	12.4	12.3	12.8
RB: other	6.6	5.6	5.0	5.0	5.4	5.0	4.4	5.0	5.8	5.1	4.9
LTM: textile/fashion cluster	4.0	4.2	4.7	4.6	5.0	5.3	6.1	6.1	5.4	5.5	6.1
LTM: other	16.4	16.8	17.4	17.7	18.1	18.0	17.8	18.2	16.9	16.3	16.1
MTM: automotive products	10.0	10.4	11.6	11.4	10.9	11.2	9.2	8.0	8.2	10.2	10.2
MTM: process industry products	8.2	7.9	8.2	8.2	8.4	8.6	8.6	9.2	8.9	8.0	8.1
MTM: engineering industry products	17.9	18.5	17.9	17.2	17.3	16.8	16.9	16.8	16.4	17.0	17.3
HTM: electronics and electrical products	10.2	10.3	9.5	9.4	9.4	9.7	11.2	11.6	11.8	11.4	10.4
HTM: other	2.8	2.7	2.8	3.2	2.7	2.7	2.5	2.0	2.5	3.0	3.2
Other transactions	0.9	1.2	1.3	1.3	1.2	1.4	1.3	1.5	2.0	1.6	1.3

Source: own calculations based on data from UNCTAD [2025].

The share of resource-based manufactures (RB) in goods exports fluctuated between 16.8% and 19.7%. Its highest value was recorded at the beginning of the second decade of the twenty-first century, while the lowest during the economic crisis in 2009. In 2024, the share of resource-based manufactures was similar to that of 2003. Between 2003 and 2024, Poland's exports of resource-based manufactures consisted predominantly of agro- and forest-based products. Their share in the exports structure followed a slight upward trend. In 2024, agro- and forest-based products accounted for almost 13% of Poland's exports, representing an increase of nearly 1.5 percentage points compared with 2003. Other resource-based products had the highest share in exports, reaching 7.5% in 2011–2012. In subsequent years, their share exhibited a downward trend, and by 2024 they accounted for less than 5% of exports.

Other transactions played a minor role in Poland's product exports, their share not exceeding 2% in the years under review.

Between 2003 and 2024, the most dynamic changes in the structure of Polish goods exports concerned the categories of low-, medium- and high-technology manufactures. During the first years of Poland's EU membership, the share of low-technology manufactures (LTM) in exports declined, while in 2010, it reached a record low of just under 20%. After a period of stagnation after 2014, the share under analysis increased to over 24% in 2021. In recent years, it has fluctuated around 22%. The main export category for low-technology manufactures consisted of other low-technology manufactures. Their share in goods exports followed the same trends as the share of low-technology manufactures. Other low-technology manufactures accounted for almost 20% of goods exports in 2003, less than 16% in 2010, and just over 16% in 2024. Between 2017 and 2022, other low-technology manufactures ranked first in terms of their share in Poland's product export structure. In the remaining years, it represented the second most important subcategory of exported products. Until 2012, exports of the textile/fashion cluster declined in importance, causing their share in the structure of goods exports to fall by 3.5 percentage points to 3.6% in 2012. In subsequent years, the share of the textile and fashion cluster exhibited a slight upward trend. In 2024, this category accounted for over 6% of Poland's goods exports.

Throughout the period under review, Poland's goods exports predominantly consisted of medium-technology manufactures (MTM). Following Poland's accession to the EU, their share in exports increased, peaking in 2007, at which time, medium-technology manufactures accounted for almost 40.5% of Poland's product exports. Since the economic crisis at the end of the first decade of the twenty-first century, the share of medium-technology manufactures in goods exports has fluctuated, although experiencing a clear downward trend, reaching a low of 33.5% in 2022.

Over the last two years of the study, the share under analysis increased, although remaining lower than in 2003.

The most important subcategory of medium-technology manufactures, and at the same time the most important subcategory of exported products overall – with the exception of the years 2017–2022 – was engineering industry products. At the beginning of the twenty-first century, these products accounted for more than one-fifth of Poland's product exports. At that time, the category of engineering industry products was dominated in Poland mainly by ships, boats and floating structures (almost 13% of MTM exports), internal combustion piston engines, parts not elsewhere specified (12.7% of MTM exports), and equipment for distributing electricity not elsewhere specified (over 6% of MTM exports) [calculations based on: UNCTAD, 2025]. However, over time, the share of engineering industry products in total goods exports gradually decreased to less than 17% in 2010. In subsequent years, the share of engineering industry products in Poland's goods exports fluctuated between 16.4% and 18.5%. In 2024, the main exported product groups within the engineering industry products were household-type equipment, electrical or otherwise, not elsewhere specified (over 5.5% of MTA exports), and internal combustion piston engine parts, not elsewhere specified (over 5% of MTM exports) [calculations based on: UNCTAD, 2025].

The second-largest subcategory of exported medium-technology manufactures consisted of automotive products, primarily motor vehicles for the transport of persons, as well as vehicle parts and accessories. Following Poland's accession to the EU, the share of automotive products in the structure of goods exports increased dynamically, rising from 9.5% in 2003 to almost 14.5% in 2009. Between 2004 and 2011, this represented the third most important subcategory of Polish exports. Since 2010, however, the share of automotive products in goods exports has fluctuated, reaching its lowest level during the COVID-19 pandemic, when it fell to 8.0–9.2%, i.e. below the level recorded in the first year of the study. Between 2023 and 2024, following a slight recovery, it once again exceeded 10%. In 2024, exports of automotive products were concentrated primarily in parts and accessories of vehicles (over 14% of MTM exports), special purpose motor vehicles for the transport of goods (6% of MTM exports), and motor vehicles for the transport of persons (over 5% of MTM exports). The share of the third category of medium-technology manufactures – process industry products – in goods exports fluctuated between 6.8% and 9.2% over the period under review.

The lowest share of high-technology manufactures (HTM) in Poland's product exports (7.5%) was recorded in the year of Poland's accession to the European Union. In subsequent years, the share of this product category increased, reaching almost 15% in 2010. However, in 2011, there was a fairly sharp drop in the share under analysis – by 3 percentage points compared to the previous year. In subsequent years, the share

of high-technology manufactures fluctuated but continued to exhibit a clear upward trend. In 2024, high-technology manufactures accounted for nearly 14% of exports, almost 5 percentage points more than in the first year of the study. Within the category of high-technology manufactures, Poland exported primarily electronics and electrical products, whose share increased from less than 7% in 2003 to almost 12.5% in 2010, before falling by almost 3 percentage points in the following year. Throughout most of the second decade of the twenty-first century, the share of these products in Polish exports fluctuated around 10%. Between 2020 and 2023, it exceeded 11%, while in 2024, the share of electronics and electrical products in product exports fell to less than 10.5%. The share of the second subcategory of high-technology manufactures in exports – other high-technology manufactures – was small. In 2003, they accounted for just over 1% of Poland's goods exports. Although the share of other high-technology manufactures in Poland's exports followed an upward trend over the period under review, in 2024 it reached a level of just 3.2%.

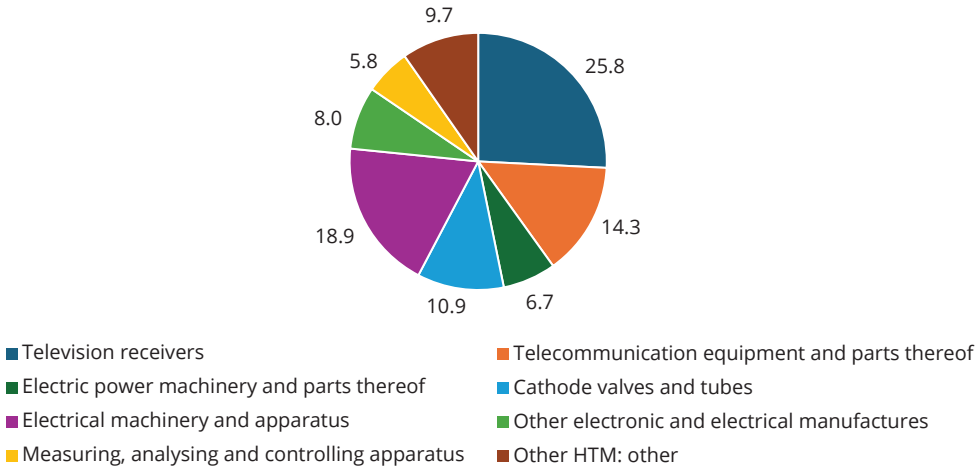
In summary, over more than two decades of Poland's EU membership, the structure of its goods exports has undergone only minor changes. Between 2003 and 2024, medium-technology manufactures dominated Poland's goods exports. Subsequent positions in the structure of exports were occupied by low-technology and resource-based manufactures, i.e. those with low technological sophistication. A positive development, however, is the rise of high-technology manufactures to fourth place in the structure of product exports, which followed an increase in their share in exports at the expense of the share of medium- and low-technology manufactures.

Taking into account the product subcategories identified by Lall, it can be observed that between 2003 and 2024 the leading positions in the structure of Polish exports were occupied by engineering industry products, other low-technology manufactures, agro- and forest-based products, and automotive products, i.e. low- and medium-technology manufactures. Only in recent years – and previously during the economic crisis at the end of the first decade of the twenty-first century – have electronics and electrical products, classified as high-technology manufactures, risen to fourth place. Nevertheless, despite an increase in their share, the importance of other high-technology manufactures (the second subcategory of products classified as high-tech) in the structure of Polish exports remained marginal.

In 2003 (Figure 4.2), Poland's high-technology manufactures exports consisted primarily of television receivers (over a quarter of its HTM exports), electrical machinery and apparatus (almost a fifth of its HTM exports), telecommunication equipment and parts thereof (over 14% of its HTM exports), cathode valves and tubes (over 10% of its HTM exports), and electric power machinery and parts thereof (almost 7% of its HTM exports). All of these product groups belonged to the category of electronics and

electrical products. Among the other high-technology manufactures, only measuring, analysing and controlling apparatus accounted for more than 5% of HTM exports (almost 6%).

Figure 4.2. Structure of Polish exports of high-technology manufactures in 2003 (%)



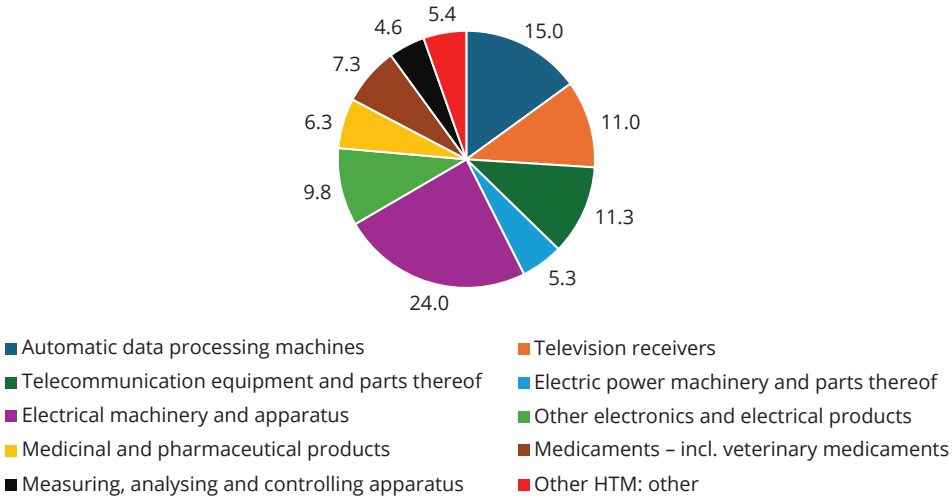
Source: own calculations based on data from UNCTAD [2025].

In 2024, the structure of Poland's high-technology manufactures exports was slightly more diversified (Figure 4.3). Electrical machinery and apparatus accounted for the largest share of high-technology manufactures exports (almost a quarter of HTM exports). Automatic data-processing machines ranked second (15% of HTM exports), despite representing only a minor share of exports of this type of goods at the beginning of the analysed period. They were followed by telecommunication equipment and parts thereof (over 11% of HTM exports) and television receivers (11% of HTM exports). The share of the latter decreased significantly (by almost 15 percentage points) over the years. Among electronics and electrical products, electric power machinery and parts thereof also exceeded the 5% share of high-technology manufactures exports. The most significant product groups within the subcategory of other high-technology manufactures exported by Poland were medicaments, including veterinary medicaments (over 7% of HTM exports), medicinal and pharmaceutical products (over 6% of HTM exports), and measuring, analysing and controlling apparatus (just under 5% of HTM exports).

In summary, between 2003 and 2024, Polish exports of high-technology manufactures showed moderate diversification. While Polish exports of television receivers and cathode valves and tubes declined significantly, exports of electrical machinery

and apparatus increased over the same period. Furthermore, new export specialisations emerged in Poland's foreign trade within the high-technology manufactures segment, namely automatic data processing machines and medicinal and pharmaceutical products. Within the subcategory of other high-technology manufactures, the share of exports of medicaments (including veterinary medicaments) also increased during the period under review.

Figure 4.3. Structure of Polish exports of high-technology manufactures in 2024 (%)



Source: own calculations based on data from UNCTAD [2025].

4.3. Poland's comparative advantages

Table 4.2 presents the revealed comparative advantages of Poland's exports. The RCA values were calculated in accordance with the definition proposed by the World Bank [World Bank, 2025]:

$$RCA_{ij} = \left(\frac{x_{ij}}{X_{it}}\right) \Big/ \left(\frac{x_{wj}}{X_{wt}}\right),$$

where:
x_{ij} – exports of the analysed product j by country i (in this case, Poland),
X_{it} – total exports of country i (Poland),
x_{wj} – global exports of the analysed product j,
X_{wt} – total global exports.

If the value of the index exceeds 1, then country *i* has a revealed comparative advantage in trade in product *j*. Otherwise, country *i* does not have an RCA in trade in product *j*.

Between 2003 and 2024, Poland revealed comparative advantages in trade in agro- and forest-based products, other low-technology manufactures, automotive products, and engineering industry products. Following its accession to the EU, Poland developed an RCA in trade in process industry products. It also periodically exhibited an RCA in trade in the textile and fashion cluster. Although Poland did not possess an RCA in overall trade in high-technology manufactures, it did exhibit an RCA in trade in selected categories of high-technology manufactures: television receivers, electrical machinery and apparatus, steam turbines and other vapour turbines and parts thereof, and – periodically – rotating electric plant and parts thereof, other power-generating machinery and parts thereof, automatic data-processing machines, and electric power machinery and parts thereof.

Table 4.2. Poland's revealed comparative advantages in trade in products between 2003 and 2024

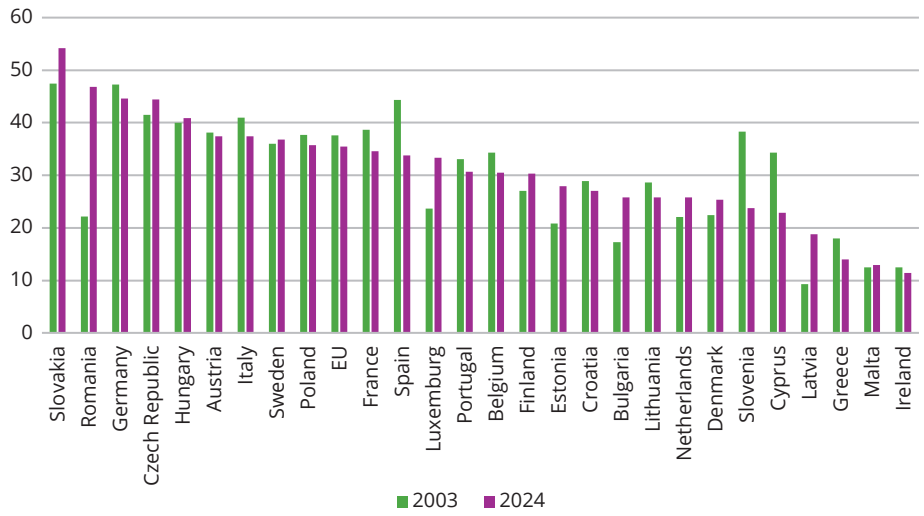
Product category	2003	2010	2020	2021	2022	2023	2024
Primary products	0.64	0.56	0.70	0.63	0.54	0.61	0.63
RB: agro- and forest-based products	1.76	1.99	2.00	1.98	2.08	2.04	2.04
RB: other	0.73	0.60	0.48	0.48	0.50	0.47	0.47
LTM: textile and fashion cluster	1.08	0.75	1.12	1.23	1.16	1.20	1.29
LTM: other	2.32	1.95	2.10	2.07	2.04	1.97	1.90
MTM: automotive products	1.03	1.86	1.32	1.24	1.33	1.33	1.41
MTM: process industry products	0.96	1.05	1.20	1.21	1.19	1.17	1.16
MTM: engineering industry products	1.48	1.21	1.18	1.25	1.33	1.26	1.27
HTM: electronics and electrical products, including	0.45	0.90	0.67	0.74	0.81	0.81	0.70
rotating electric plant and parts thereof	0.74	0.83	1.05	0.99	1.28	1.20	1.12
other power-generating machinery and parts thereof	0.48	1.31	1.32	1.37	1.49	0.82	0.69
automatic data-processing machines	0.05	1.04	1.04	1.00	1.15	0.98	1.04
television receivers	4.24	6.97	3.60	4.04	4.89	3.86	3.89
electric power machinery and parts thereof	1.16	0.95	0.83	0.90	1.03	1.08	1.07
electrical machinery and apparatus	1.06	1.27	2.09	2.54	2.47	2.76	2.06
HTM: other, including	0.21	0.40	0.39	0.34	0.45	0.48	0.50
steam turbines and other vapour turbines and parts thereof	3.05	2.90	3.02	2.06	1.79	1.99	2.23
Other transactions	0.27	0.17	0.22	0.26	0.37	0.25	0.24

Source: own calculations based on data from UNCTAD [2025].

4.4. Technology intensity of Polish goods exports compared with the European Union

Throughout the period covered by the study, the Member States of the European Union were defined as the 27 countries that were members of the EU in 2024. An analysis of the technology intensity of Polish goods exports compared with the EU shows that, in 2003, the share of medium-technology manufactures in Polish exports was similar to the EU average (Figure 4.4). The situation differed, however, in the case of high-technology manufactures – their share in Polish exports was almost 10 percentage points lower than the EU average (Figure 4.5). In 2024, the situation remained similar. The difference between the share of medium-technology manufactures in Polish exports and their share in EU exports amounted to only 0.2 percentage points. Meanwhile, the share of high-technology manufactures in EU exports remained higher than in Polish exports, although the gap decreased to approx. 6 percentage points.

Figure 4.4. Share of medium-technology manufactures in EU Member States' goods exports in 2003 and 2024 (%)

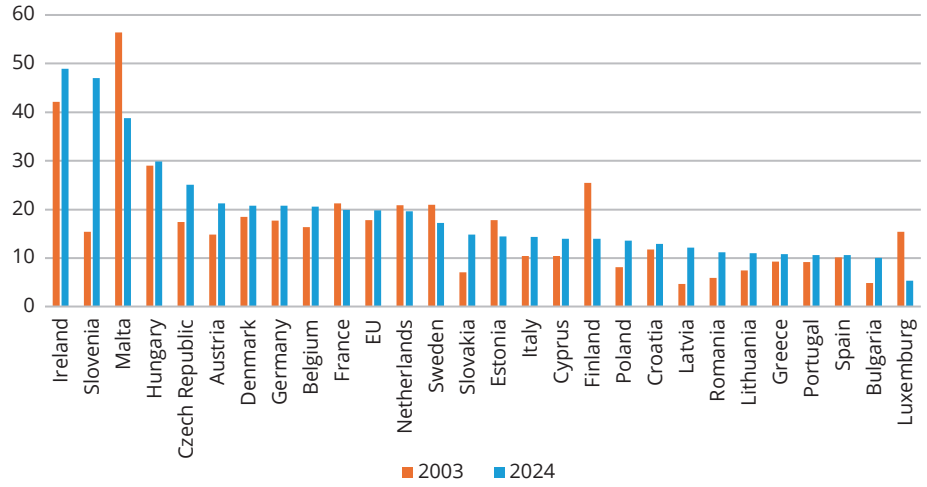


Source: own calculations based on data from UNCTAD [2025].

In 2003, the leading exporters of medium-technology manufactures were primarily the large "old", EU Member States (Germany, France, Italy), several EU candidate countries (Slovakia, the Czech Republic, Slovenia, and Hungary), as well as smaller EU economies such as Austria. In 2024, among the "old" EU Member States, Germany

and Austria maintained their positions, as did several "new" Member States (the Czech Republic, Slovakia and Hungary), while Romania – which recorded the second-highest share of medium-technology manufactures in exports after Slovakia – joined the group of leaders. The lowest share of medium-technology manufactures in exports was recorded in smaller EU countries, often island nations. In 2003, these included Latvia, Malta and Ireland, and in 2024 the countries concerned were Ireland, Malta and Greece. In both 2003 and 2024, Poland ranked near the bottom of the top ten in this classification.

Figure 4.5. Share of high-technology manufactures in EU Member States' exports in 2003 and 2024 (%)



Source: own calculations based on data from UNCTAD [2025].

In the case of high-technology manufactures, the leading exporters in 2003 were Malta (56.4% of exports), Ireland (42.1%) and Hungary (29%), although in Malta's case the absolute value of exports remained low. Meanwhile, the lowest-ranked countries in this classification were EU candidate countries: Latvia (4.7%), Bulgaria (4.9%), and Romania (5.9%). In 2024, the highest shares of high-technology manufactures in EU exports were recorded in Ireland (almost 49%) and Slovenia (47%), followed by Malta (just under 39%, despite a low export value) and Hungary (almost 30%), while the lowest shares were recorded in Luxembourg (just over 5%), Bulgaria (10%), Portugal (10.6%) and Spain (10.6%). In 2003, Poland ranked 22nd among exporters of high-technology manufactures; by 2024, it had advanced to 18th place. A comparison of 2024 data with 2003 data shows that the share of high-technology manufactures increased in all "new" EU Member States, with the exception of Estonia.

4.5. Conclusions

Between 2003 and 2024, there were no fundamental changes in the structure of Polish goods exports in terms of technology sophistication; nevertheless, the technology intensity of goods exported from Poland did improve slightly. Although medium-technology manufactures remained the most important export category, their share in the exports structure declined over the period under review. The share of low-technology manufactures in the structure of Polish exports also decreased, while the share of high-technology manufactures increased. The most significant positive changes in the structure of Poland's goods exports occurred during the first years of Poland's EU membership. Following the financial and economic crisis at the end of the first decade of the twenty-first century, however, this process came to a halt, and there were even signs of regression in terms of exports of high-technology manufactures. Only in recent years has the share of high-technology manufactures in Poland's product exports begun to increase gradually once again, although it still remained lower than at the end of the first decade of the twenty-first century. Among high-technology manufactures, Poland primarily exported electronics and electrical products. Nevertheless, during the period under review, the share of other high-technology manufactures increased slightly. As a result, the export structure of high-technology manufactures became somewhat more diverse.

The most important product subcategories in terms of their share of Polish exports were engineering industry products, which belong to the medium-tech category, and other low-technology manufactures, although their share in goods exports decreased over the period under review. In terms of the export structure, the third-largest share was held by agro- and forest-based products, with the exception of 2004–2011, when this position was occupied by automotive products, classified as medium-technology manufactures. At that time, Poland exhibited a revealed comparative advantage in trade in the aforementioned product subcategories.

Since 2020, electronics and electrical products, which belong to the category of high-technology manufactures, have risen to fourth place in the export structure, which indicates a gradual shift from specialisation in resource-based and labour-intensive products (with the exception of specialisation in agro- and forest-based products) towards high-tech products, although their share in Poland's exports – less than 14% in 2024 – remains relatively low. Despite Poland's integration with the EU, the technology intensity of its exports has remained low to medium.

Although Poland did not exhibit a revealed comparative advantage in overall trade in high-technology manufactures between 2003 and 2024, it did possess a revealed

comparative advantage in trade in selected product groups belonging to this category. For example, Poland exhibited an RCA in trade in television receivers and in electrical machinery and apparatus, which were among the most important groups of high-technology manufactures exported by Poland.

Between 2003 and 2024, the technology intensity of Poland's goods exports was lower than the EU average. Admittedly, the share of medium-technology manufactures in Poland's exports was consistent with the EU average during the period under review, but the share of high-technology manufactures in Poland's exports remained significantly lower than the EU average. However, it is encouraging that the indicator analysed has shown an upward trend in recent years and has gradually converged towards the EU average, although Polish exports in this product category still lagged significantly behind export leaders such as Ireland, Slovenia, Hungary and the Czech Republic. This suggests that Poland still has a long way to go in this area, particularly if the technology intensity of exports from other EU countries in Central Europe, such as the Czech Republic, Hungary and Slovenia, is treated as the benchmark.

Given the relatively low technology intensity of Poland's product exports compared with other EU Member States, Poland should implement a twin-track market intervention strategy. On the supply side, economic policy should stimulate the development of the high-tech manufacturing sector, which could be achieved, *inter alia*, through a system of fiscal and subsidy incentives, stabilisation of the institutional and regulatory environment, and the active attraction of adequate FDI. On the demand side, however, it would be worthwhile to further develop pro-export support instruments, e.g. through trade missions. A key element of this strategy should also be the active pursuit of export niches in the area of high-technology manufactures, where Polish exporters have the potential to build lasting comparative advantages.

References

Barrios, S., Görg, H., Strobl, S. (2003). Explaining Firms' Export Behaviour: R&D, Spillovers and the Destination Market, *Oxford Bulletin of Economics and Statistics*, 65(4), pp. 475–496. DOI: 10.1111/1468-0084.t01-1-00058.

Braunerhjelm, P., Thulin, P. (2008). Can Countries Create Comparative Advantages? R&D Expenditures, High-Tech Exports, and Country Size in 19 OECD Countries 1981–1999, *International Economic Journal*, 22, pp. 95–111. DOI: 10.1080/10168730801887026.

Chen, Y., Zhang, L., Lei, X., Chen, Y. (2023). Research on the Influence of R&D Investment on High-Tech Product Trade in China, *Proceedings of the 2nd International Academic Conference on Blockchain, Information Technology and Smart Finance (ICBIS 2023)*, pp. 792–799. DOI: 10.2991/978-94-6463-198-2_82.

Czarny, E., Folfas, P. (2020). Polska wymiana towarowa z zagranicą w latach 2004–2017. In: *15 lat wspólnego członkostwa w Unii Europejskiej: osiągnięcia i aktualne wyzwania dla polskiej i niemieckiej polityki gospodarczej* (pp. 65–77), J. Wandel, K. Kamińska (Eds.). Warszawa: Oficyna Wydawnicza SGH.

Czarny, E., Folfas, P., Szarek-Piaskowska, A. (2023). *Dobra najbardziej zaawansowane technologicznie w handlu wybranych ugrupowań integracyjnych i ich państw członkowskich*. Warszawa: Oficyna Wydawnicza SGH.

European Investment Bank (2022). *Business Resilience in the Pandemic and Beyond. Adaptation, Innovation, Financing and Climate Action from Eastern Europe to Central Asia*. Luxembourg.

Filipescu, D., Prashantham, S., Rialp, A., Rialp, J. (2013). Technological Innovation and Exports: Unpacking Their Reciprocal Causality, *Journal of International Marketing*, 21(1), pp. 23–38. DOI: 10.1509/jim.12.0099.

Gawlikowska-Hueckel, K., Śledziewska, K. (2016). Handel zagraniczny Polski po akcesji Polski do UE ze szczególnym uwzględnieniem dóbr wysokich technologii. In: *Analiza handlu zagranicznego Polski w świetle najnowszych koncepcji teoretycznych. Implikacje dla polityki gospodarczej w dobie kryzysu* (pp. 44–72), K. Gawlikowska-Hueckel, S. Umiński (Eds.). Warszawa: Wydawnictwo Naukowe Scholar.

Gehl Sampath, P., Vallejo, B. (2018). Global Value Chains and Upgrading: What, When and How?, *MERIT Working Papers*, 016, pp. 1–31.

Geng, D., Kali, R. (2021). Trade and Innovation: Unraveling a Complex Nexus, *International Journal of Innovation Studies*, 5(1), pp. 23–34. DOI:10.1016/j.ijis.2021.01.001.

Hatzichronoglou, T. (1997). *Revision of the High-Technology Sector and Product Classification*. Paris: OECD Publishing. DOI: 10.1787/134337307632.

Heijs, J., Valdiviezo, G. (2013). *Innovation and International Trade: A Non-Linear Relationship*, https://repositorio.altecasociacion.org/bitstream/handle/20.500.13048/772/Innovation%20and%20international%20trade%20a%20non-linear%20relationship.pdf?sequence=1&isAllowed=y (accessed: 24.07.2025).

Jaffe, S., Gordon, P. (1993). *Exporting High-Value Food Commodities: Success Stories from Developing Countries*. Washington: World Bank.

Kiriyama, N. (2012). Trade and Innovation: Synthesis Report, *OECD Trade Policy Papers*, 135. DOI: 10.1787/5k9gwprtbtxn-en.

Lall, S. (2000). The Technological Structure and Performance of Developing Country Manufactured Exports 1985–98, *Oxford Development Studies*, 28(3), pp. 337–369. DOI: 10.1080/713688318.

Melitz, M., Redding, S. (2021). Trade and Innovation, *CEP Discussion Paper*, 1777.

Michalski, B. (2013). Zaawansowanie technologiczne polskiego eksportu w pierwszej dekadzie XXI wieku, *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 315, pp. 607–618.

Nguyen Si Minh, H., Pham Minh, T., Do Minh, H., Van-Chung, D. (2025). Effects of Innovation on Trade: New Empirical Evidence From Vietnam, *Proceedings of the International Conference on Emerging Challenges: Sustainable Strategies in the Data-driven Economy (ICECH 2024)*, pp. 130–151. DOI: 10.2991/978-94-6463-694-9_9.

Radło, M.J., Szarek-Piaskowska, A. (2022). Competitiveness of International Merchandise Trade: The Case of Poland, *Ekonomia – Wroclaw Economic Review*, 28(2), pp. 7–22. DOI: 10.19195/2658-1310.28.2.1.

Saliya, C. (2025). The Critical Role of R&D in High-Tech Export Competitiveness: Innovation as the Key Driver of Economic Growth, *International Journal of Latest Technology in Engineering Management and Applied Science*, 14(3), pp. 472–478. DOI: 10.51583/IJLTEMAS.2025.140300053.

Sandu, S., Ciocanel, B. (2014). Impact of R&D and Innovation on High-Tech Export, *Procedia Economics and Finance*, 15, pp. 80–90. DOI: 10.1016/S2212-5671(14)00450-X.

Topcu, B. (2018). The Effect of R&D Expenditures on High-Tech Manufacturing Industry Export: The Case of OECD Countries, *Social Sciences Studies Journal*, 16(4), pp. 1177–1183. DOI: 10.26449/sssj.489.

Trindade, J.R., Pereira de Oliveira, W. (2017). Padrão de Especialização Primário-Exportador e Dinâmica de Dependência no Período 1990–2010, na Economia Brasileira, *Ensaios FEE*, 37(4), pp. 1059–1092.

UNCTAD (2025). *Merchandise Trade Matrix, Annual (Analytical)*, https://unctadstat.unctad.org/datacentre/dataviewer/US.TradeMatrix (accessed: 24.07.2025).

World Bank (2025). *Trade Indicators*, https://wits.worldbank.org/wits/wits/witshelp/Content/Utilities/e1.trade_indicators.htm (accessed: 24.07.2025).

Yasar, S., Dayanan, D. (2024). The Role of R&D Expenditures on High Technology Product Exports: A Panel Causality Analysis for OECD Countries, *EKOIST Journal of Econometrics and Statistics*, 41, pp. 151–160. DOI: 10.26650/ekoist.2024.41.1553410.

Zapata, A.N., Arrazola, M., de Hevia, J. (2024). Determinants of High-Tech Exports: New Evidence from OECD Countries, *Journal of the Knowledge Economy*, 15, pp. 1103–1117. DOI: 10.1007/s13132-023-01116-z.

Chapter 5

Poland's Income Convergence Relative to the European Union

Mariusz Próchniak

5.1. Introduction

The aim of this chapter is to present the historical paths and current macroeconomic performance of the 11 Central and Eastern European (CEE) countries that joined the European Union (EU) in 2004, 2007 and 2013, namely Poland, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Slovakia and Slovenia (EU-11). As part of the analysis of past development patterns, a study of the income convergence of these countries relative to the 14 Western European countries that are current members of the EU (EU-14) was used.[1]

This chapter builds on earlier research on this topic presented in previous editions of the *Competitiveness Report*. Previous studies on income convergence include works by, *inter alia*, Matkowski, Rapacki and Próchniak [2016a], Próchniak [2017, 2022, 2023, 2024, 2025], and Rapacki, Maszczyk, Lissowska, Próchniak and Sulejewicz [2025]. The 2013 edition of the *Competitiveness Report* also contains an analysis of regional convergence across all EU countries [Matkowski, Próchniak, 2013].

5.2. Theoretical foundations of income convergence analysis

The theoretical framework for analysing income convergence is provided by economic growth models. Neoclassical models of economic growth [e.g. Solow, 1956; Mankiw, Romer, Weil, 1992] confirm the occurrence of conditional β-convergence. This phenomenon arises when less developed countries (with lower levels of GDP

[1] The study included the following Western European countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and Sweden. The UK was excluded from the analysis as it is no longer a member of the EU.

per capita) achieve faster economic growth rates than more developed countries. Convergence is conditional because it only occurs when all countries are moving towards the same long-run equilibrium (steady state). The β-convergence hypothesis can be explained using the Solow model as an example [see, e.g., Rapacki, Próchniak, 2012; Próchniak, Witkowski, 2012].

In the Solow model, the fundamental equation describing the dynamics of an economy moving towards the steady state takes the following form:

$$\dot{k} = sf(k) - (n + a + \delta)k, \tag{5.1}$$

where: k – capital per unit of effective labour in year t, $\dot{k}$ – the change in k per unit of time (mathematically it is the time derivative of k), s – savings rate, $f(k)$ – production function (expressed per unit of effective labour), n – population growth rate, a – rate of exogenous technological progress, δ – capital depreciation rate.

In the analysis of the Solow model with technological progress, the symbols k and $f(k)$ stand for capital and output calculated per unit of effective labour, respectively, where effective labour is defined as the product of the level of technology and the labour force.

Assuming a Cobb-Douglas production function of the form $f(k) = k^{\alpha}(0 < \alpha < 1)$, then equation 5.1 can be transformed to:

$$\dot{k} = sk^{\alpha} - (n + a + \delta)k. \tag{5.2}$$

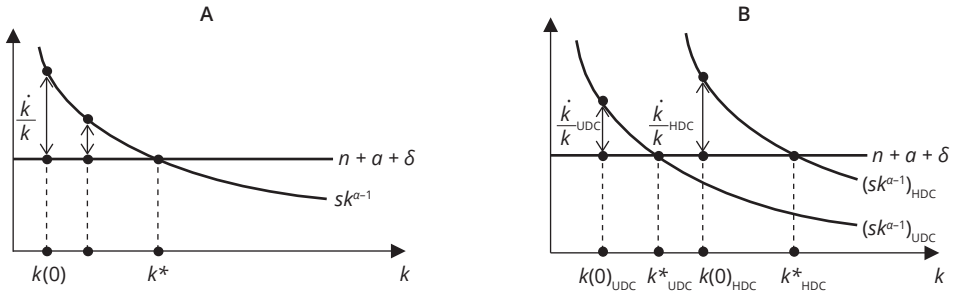
Dividing equation 5.2 by k yields the formula for the rate of capital growth per unit of effective labour during the transition towards the steady state:

$$\frac{\dot{k}}{k} = sk^{\alpha-1} - (n + a + \delta). \tag{5.3}$$

Since output is directly proportional to capital, an analogous equation characterises the dynamics of GDP calculated per unit of effective labour.

The best way to illustrate the convergence hypothesis is to analyse equation 5.3 graphically. This is shown in Figure 5.1, where the growth rate is equal to the vertical distance between the curve $sk^{\alpha-1}$ and the straight line $n + a + \delta$. As illustrated, an economy that starts from an initial capital level of $k(0)$ and reaches a capital stock in long-run equilibrium k^* shows a declining rate of economic growth. Convergence is conditional, as it only occurs when both economies are moving towards the same long-run equilibrium.

Figure 5.1. Economic growth in the Solow model



Notes: HDC – highly developed country, UDC – underdeveloped country, k – tangible capital stock, s – savings rate, n – population (labour force) growth rate, a – rate of technological progress, δ – capital depreciation rate, A – a common steady state for the highly developed and underdeveloped countries, B – different steady states for the highly developed and underdeveloped countries.

Source: own elaboration.

To illustrate the conditional nature of the phenomenon of convergence, let us consider the example of two countries: a highly developed country and an underdeveloped country with different savings rates. Since the savings rate in the developed country is higher, the capital stock in long-run equilibrium is also higher, as illustrated in part B of Figure 5.1. Although the highly developed country starts from a higher level of capital, it may also experience faster economic growth as it moves towards a different long-run equilibrium state. In such a case, convergence will not occur.

An important objective of the empirical study is to estimate the value of the parameter β, which measures the rate of the convergence process to the steady state, according to the following equation:

$$\frac{\dot{y}}{y} = \beta\left(\ln y^* - \ln y\right), \tag{5.4}$$

where: y – output per unit of effective labour in year t, $\dot{y}$ – change of y per unit of time (time derivative), y^* – output per unit of effective labour in the steady state.

The parameter β indicates the distance towards the steady state that the economy covers in a single period (year). For example, when $\beta = 0.02$, the economy covers 2% of the distance each year.

Another type of convergence is σ-convergence, which occurs when the income differential between countries decreases over time. The income differential can be measured by the standard deviation, variance or coefficient of variation of GDP *per capita* levels between countries or regions.

From a theoretical perspective, σ-convergence is a necessary but not sufficient condition for β-convergence to occur. Thus, it is possible (although unlikely) for the

income gap between economies to widen over time while the less developed country simultaneously records a faster rate of economic growth. This can occur when a less developed country achieves a rate of economic growth that is sufficiently rapid to outperform a more developed country in terms of income level, resulting in a larger development gap in the final period than in the initial year.

To verify the occurrence of absolute β-convergence, the following regression equation was estimated:

$$\frac{1}{T}\ln\frac{y_T}{y_0} = \alpha_0 + \alpha_1 \ln y_0 + \varepsilon_t, \tag{5.5}$$

where: y_T and y_0 – the *per capita* income in the final and initial year, ε_t – the random component.

The dependent variable is therefore the average annual growth rate of real GDP *per capita* at purchasing power parity (PPP) between period T and 0, while the independent variable is the natural logarithm of GDP *per capita* in the initial period. If the α_1 parameter is negative and statistically significant (a significance level of 5% was assumed in the empirical analysis), β-convergence occurs. In this situation, the value of the β coefficient, which measures the rate of convergence, can be calculated as:

$$\beta = \frac{1}{T}\ln\left(1+\alpha_1 T\right). \tag{5.6}$$

To verify the occurrence of σ-convergence, a trend line for the income differential between countries was estimated:

$$sd\left(\ln y_t\right) = \alpha_0 + \alpha_1 t + \varepsilon_t, \tag{5.7}$$

where: *sd* – standard deviation, t – time ($t = 1, \ldots, 33$ for the years 1993–2025).

Thus, the dependent variable is the standard deviation of the natural logarithms of GDP *per capita* between countries, while the independent variable is time. If the α_1 parameter is negative and statistically significant, σ-convergence occurs.

5.3. Income convergence of the EU-11 countries towards the EU-14 countries – results of the empirical study

The study covers the years 1993–2025. All calculations were also made for the three sub-periods: 1993–2004, 2004–2015 and 2015–2025, making it possible to analyse the temporal stability of the studied phenomenon. The first of the specified sub-periods

extends from the end of the transition recession in many EU-11 countries, including Poland, to the largest enlargement of the EU involving Central and Eastern Europe. The remaining two sub-periods, on the other hand, cover the first (in most cases) and second decade, respectively, of the EU-11 countries' EU membership.

Table 5.1. Results of the estimation of regression equations describing β-convergence

Period	α_0	α_1	*t*-stat. (α_0)	*t*-stat. (α_1)	*p*-value (α_0)	*p*-value (α_1)	R^2	β-convergence	β
25 countries of the enlarged EU									
1993–2025	0.2026	–0.0177	7.83	–6.97	0.000	0.000	0.6784	yes	0.0178
1993–2004	0.1913	–0.0155	4.20	–3.47	0.000	0.002	0.3443	yes	0.0157
2004–2015	0.2469	–0.0220	4.57	–4.30	0.000	0.000	0.4456	yes	0.0222
2015–2025	0.2374	–0.0204	3.93	–3.61	0.001	0.001	0.3617	yes	0.0206
2 regions (EU-11 and EU-14)									
1993–2025	0.2530	–0.0228	–	–	–	–	1.0000	yes	0.0230
1993–2004	0.2219	–0.0191	–	–	–	–	1.0000	yes	0.0193
2004–2015	0.3719	–0.0339	–	–	–	–	1.0000	yes	0.0345
2015–2025	0.5014	–0.0451	–	–	–	–	1.0000	yes	0.0462

Notes: α_0 and α_1 – parameters in the regression equation (respectively: constant and slope), *t* – *t*-student statistic, *p* – significance level (*p-value*), R^2 – coefficient of determination, β – parameter measuring the rate of β-convergence.

Source: own elaboration based on IMF data.

The calculations used time series of real GDP *per capita* at purchasing power parity (expressed in USD), sourced from the International Monetary Fund's data [IMF, 2025].

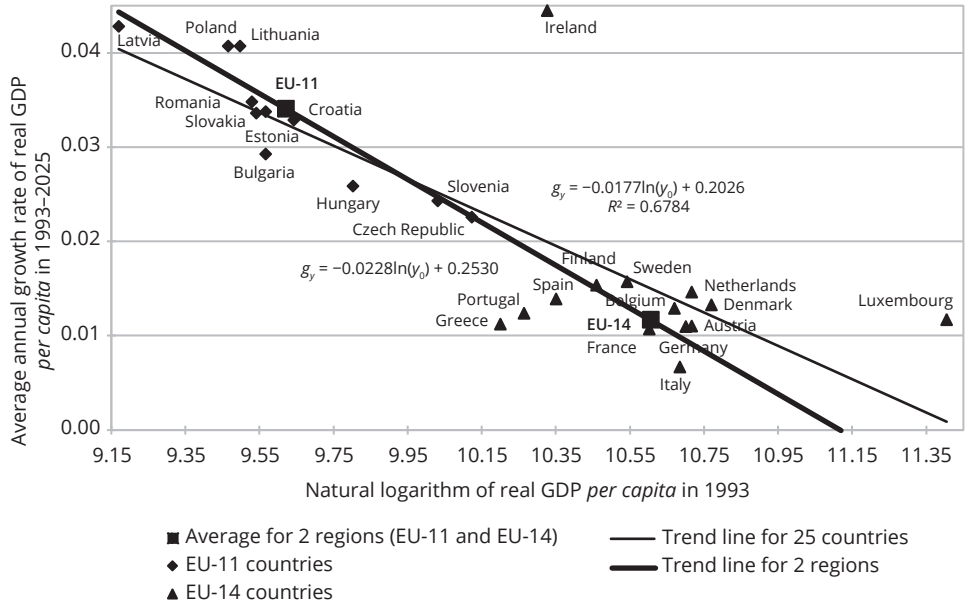
The results of the analysis of β-convergence between the EU-11 and EU-14 are shown in Table 5.1 and Figure 5.2. Convergence is analysed both within the EU-25 as a whole and between the two regions comprising the EU-11 and EU-14. The aggregated data for both groups consists of weighted averages, with variable weights reflecting the population of each country included in a given group and year.

The results confirm the occurrence of clear income convergence of the EU-11 towards the EU-14 over the entire analysed period of 1993–2023. Convergence was observed both among the 25 countries included in the study and between the two areas under consideration (EU-11 and EU-14). Countries with lower income levels in 1993 showed, on average, faster economic growth rates in 1993–2025 than the countries that were more developed at the outset. Since the less developed countries in 1993 were the CEE countries, these results confirm the clear convergence of the EU-11 countries towards the average income level in Western Europe.

Analysis of Figure 5.2 shows that the distribution of points representing individual countries is limited relative to the negatively sloping trend line, which is reflected in the

relatively high value of the coefficient of determination of 68%. Thus, differences in initial income levels allow for accounting for over two-thirds of the variation in economic growth rates between 1993 and 2025.

Figure 5.2. Relationship between the growth rate of GDP per capita in 1993–2025 and the level of GDP *per capita* in the initial period



Notes: g_y – growth rate of real GDP *per capita* at PPP in 1993–2025, $\ln(y_0)$ – natural logarithm of real GDP *per capita* at PPP in 1993, R^2 – coefficient of determination.

Source: own elaboration based on IMF data.

By examining the points representing individual countries, it is possible to compare their relative situations and, from this perspective, assess the changes in their competitive position over the entire analysed period. Among the CEE countries in the study group, Latvia, Lithuania and Poland recorded the fastest growth rates. These countries showed an average annual economic growth of over 4% between 1993 and 2025, despite relatively low initial income levels. Romania, Slovakia, Estonia and Croatia also recorded relatively rapid rates of economic growth, at approx. 3.5%. The results achieved by these countries reinforced the group-wide trend towards convergence. As can be seen, Poland's situation compares favourably with other countries, ranking second (jointly with Lithuania) among the 11 CEE countries in terms of average economic growth rate in 1993–2025 (with a result of 4.1%), which was one of the key factors contributing to the strengthening of the competitive position of the Polish economy.

The aggregated data for the two indicated areas (EU-11 and EU-14) also confirms the occurrence of convergence in 1993–2025. In Figure 5.2, the points representing these two areas are marked with squares. The EU-11 group as a whole recorded a faster growth rate than the EU-14 area, with a much lower initial income level.

The β-coefficients measuring the speed of the convergence process amount to 1.78% for the 25 EU countries and 2.30% for the two areas analysed separately. These coefficients make it possible to estimate the time needed to narrow the development gap between the countries studied. Namely, if the average economic growth trend of 1993–2025 is maintained, the countries of the enlarged EU will still need approx. 30–40 years to halve the gap to a common hypothetical long-run equilibrium state. This result was calculated as follows: $-\ln(0.5)/0.0178 = 38.9$ years and $-\ln(0.5)/0.0229 = 30.1$ years. The results represent a slow convergence of the EU-11 countries towards Western Europe. Based on these estimates, it is difficult to expect a rapid alignment of income between Poland and other CEE countries on the one hand, and Western Europe on the other, in the medium term.

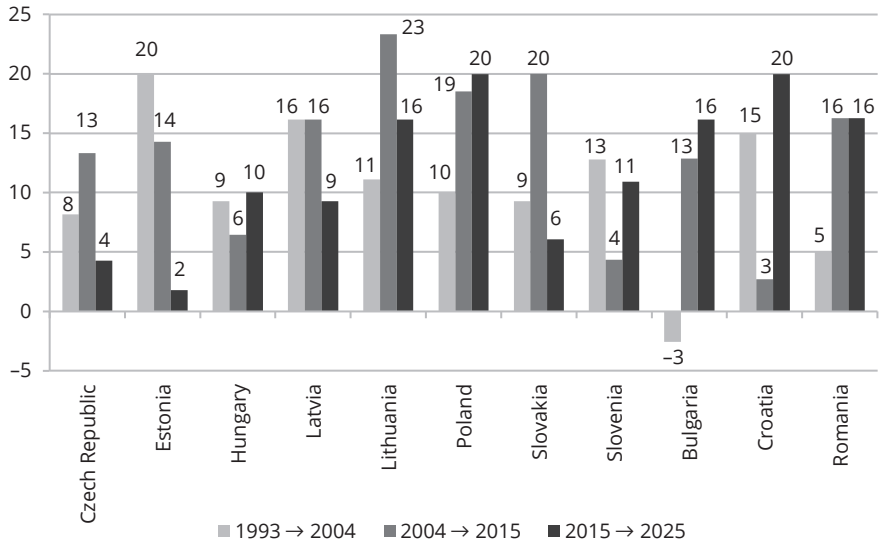
These results should be interpreted with caution, as they are based on model assumptions that may not hold in reality. The model assumes the occurrence of declining marginal productivity of capital (in line with the neoclassical production function) and the fact that economies move towards a steady state with a declining rate of economic growth, which is reached only asymptotically. Therefore, when interpreting these results, it would be meaningful to quote the half-life rather than the period needed to close the income gap completely. It is also worth comparing these results with other forecasts, presented, for example, in the *Report of the SGH Warsaw School of Economics and the Economic Forum*, which show that Poland will catch up with Western Europe within little more than a decade. However, given the events of the past few years (the COVID-19 pandemic, the war in Ukraine, the energy crisis), such forecasts now appear rather unrealistic [Próchniak, Lissowska, Maszczyk, Rapacki, Sulejewicz, 2019].

It is also worth examining how the stability of convergence processes has evolved over time. It appears that the rate of convergence was very different in the identified sub-periods. The instability of the rate of convergence in the countries studied resulted, *inter alia*, from the global crisis, the COVID-19 pandemic, the war in Ukraine, as well as the influence of various institutional factors affecting economic growth, including those related to EU membership. Nevertheless, convergence was observed in all the sub-periods identified, although the fit of the regression line to the empirical data varied. The previously described model confirmed the existence of β-convergence among the 25 EU countries in the years 1993–2004, i.e. prior to EU enlargement, although the coefficient of determination was only 34%. The occurrence of convergence

during this period was partly due to the fact that the integration anchor triggered by EU membership began to take effect much earlier, i.e. even before the official date of accession. The rate of convergence accelerated between 2004 and 2015, which was undoubtedly due to the enlargement of the EU.[2] The strong trend towards convergence noted in the first decade of EU membership weakened in the subsequent decade. This was largely due to the occurrence of crisis phenomena related to the COVID-19 pandemic and the war in Ukraine, and the disruption of the previously stable economic growth paths of the countries studied.

The β-convergence results presented above are averaged for the entire region. As Figure 5.2 demonstrates, the different CEE countries showed different economic growth dynamics and varying degrees of convergence towards Western Europe. The convergence of individual EU-11 countries relative to the EU-14 in the sub-periods identified is therefore worth analysing.

Figure 5.3. Reduction in the income gap between the EU-11 countries and the EU-14 across three successive sub-periods (p.p.)



Notes: in each year, GDP *per capita* at PPP in the EU-14 was assumed to be 100.
Source: own elaboration based on IMF data.

Figure 5.3 illustrates the extent (expressed in percentage points) to which the income gap between the individual EU-11 countries and the EU-14 narrowed

[2] The positive impact of EU membership on the economic growth of the 11 CEE countries was also confirmed in the paper by Rapacki and Próchniak [2019].

between 1993–2004, 2004–2015 and 2015–2025. An analysis of the data presented in the graph shows that individual EU-11 countries reduced the income gap with Western Europe at different rates across the three sub-periods identified. In Estonia and Slovenia, this process was most rapid during the first sub-period, i.e. from 1993 to 2004. Prior to its accession to the EU, Estonia reduced the development gap with Western Europe by an impressive 20 percentage points. In the following two sub-periods, the country's convergence rate was slower, and its income gap with the EU-14 decreased by 14 percentage points in 2004–2015 and by only 2 percentage points in 2015–2025, respectively.

In the Czech Republic, Romania, Latvia, Lithuania and Slovakia, the most rapid reduction in the income gap relative to Western Europe occurred in the period 2004–2015, i.e. in the first years of their EU membership. The results achieved by Lithuania are particularly noteworthy. Between 2004 and 2015, the country reduced its income gap relative to the EU-14 cluster by 23 percentage points, which should be regarded as a major success. This also represented the fastest pace of convergence among all EU-11 countries during the periods under discussion.

The remaining four EU-11 countries – Hungary, Poland, Bulgaria and Croatia – achieved their best results in terms of the rate of income convergence during the third sub-period, i.e. in the years 2015–2025. During that period, Poland and Croatia reduced their income gap relative to Western Europe by 20 percentage points each, which was the best result among all countries in the EU-11 cluster during that decade.

Focusing on Poland, it can be concluded that in the three identified sub-periods it achieved progressively better results in terms of reducing the income gap relative to Western Europe. While Poland managed to make up 10 percentage points of the development gap between 1993 and 2004, the result was 19 percentage points and 20 percentage points in the periods 2004–2015 and 2015–2025, respectively. In the case of Poland, an important role in accelerating the convergence process following EU enlargement was played by European funds, which increased the competitiveness of the Polish economy. Poland was the largest beneficiary of EU funds under the 2007–2013 budget framework. The inflow of funds provided by the EU under various aid programmes positively affected the growth dynamics of the Polish economy on both the demand and supply sides, thanks to which Poland performed relatively well in terms of economic growth rates in recent years (e.g. it was the only EU country to avoid recession during the global financial crisis). The EU 2014–2020 budget, together with the continuation of the large inflow of structural funds to the new Member States, also helped Poland maintain a faster pace of convergence towards the EU-14 in terms of development in the final sub-period analysed.

A key driver of Poland's convergence with Western Europe has also been the accumulation of human capital, which is a highly important factor of production. The rapid growth in human capital stock was the result of the combined impact of numerous factors, including improvements in public health. These improvements were driven, for example, by better access to doctors and hospitals, partly due to the development of private healthcare, as well as by broader preventive healthcare measures and greater attention to environmental issues.

The expansive fiscal and monetary policies pursued in Poland over the last decade by the government and the central bank have also contributed to maintaining strong economic momentum (despite restrictive measures in some years). Large-scale infrastructure investments – including, for example, the continued construction of motorways and expressways (e.g. Via Baltica and Via Carpatia), the modernisation of railway lines and the purchase of new rolling stock, the canal through the Vistula Spit, and the construction of the tunnel under the Świna River in Świnoujscie – as well as large social programmes resulting in an increase in disposable household income, are just some examples of measures that stimulated the Polish economy at that time.

A key factor contributing to rapid economic growth in Poland and other CEE countries was expenditure on research and development (R&D). In 2004, i.e. when Poland joined the EU, R&D expenditure amounted to 0.55% of GDP in Poland, while the (unweighted) average for the 11 CEE countries stood at 0.76% of GDP [Eurostat, 2025]. In most EU-11 countries (with the exception of the Czech Republic, Croatia and Slovenia), R&D expenditure was below 1% of GDP at the time. In the group of CEE countries as a whole, low R&D expenditure persisted until 2010 (in all years from 2000 to 2010, expenditure on research and development accounted for less than 1% of GDP). In the CEE cluster, the 1% of GDP threshold was exceeded in 2011, and since then, the EU-11 group has spent an average of over 1% of GDP on R&D activities each year. In Poland, this threshold was reached in 2015 and – with the exception of 2016 – R&D expenditure has been growing steadily since 2017, reaching 1.56% of GDP in 2023, compared with the average for the EU-11 group of 1.30% of GDP.[3]

Poland currently ranks fourth in the EU-11 group in terms of relative income per capita (at PPP). According to IMF data from October 2025, Poland's GDP *per capita* in 2025 was 81% of the average income *per capita* in Western Europe (EU-14), outperformed only by the Czech Republic (87%) and Lithuania (84%). This represents a significant improvement compared to data from just over a decade earlier, when

[3] More information on the R&D sector, which also allows for broader conclusions, can be found in the other chapters of this monograph. See also the analysis presented by the author in Chapter 6.

Poland ranked near the bottom of the group. It is to be hoped that, despite the war in Ukraine, Poland will continue its successful development trends and further reduce its development gap relative to Western Europe in the years to come.

We measure the σ-convergence of CEE countries towards Western Europe by analysing changes in the standard deviation of the natural logarithm of GDP *per capita* across the 25 EU countries, as well as between the two analysed areas (EU-11 and EU-14). The results of the trend line estimation for the standard deviations are shown in Table 5.2, while Figure 5.4 provides a graphical representation of the results.

Table 5.2. Results of the estimation of regression equations describing σ-convergence

Period	α_0	α_1	*t*-stat. (α_0)	*t*-stat. (α_1)	*p*-value (α_0)	*p*-value (α_1)	R^2	σ-convergence
25 countries of the enlarged EU								
1993–2025	0.5765	–0.0082	80.76	–22.43	0.000	0.000	0.9420	yes
1993–2004	0.5697	–0.0054	53.78	–3.74	0.000	0.004	0.5834	yes
2004–2015	0.4632	–0.0074	63.10	–7.44	0.000	0.000	0.8469	yes
2015–2025	0.3883	–0.0059	85.92	–8.89	0.000	0.000	0.8977	yes
2 regions (EU-11 and EU-14)								
1993–2025	0.5245	–0.0122	92.38	–41.88	0.000	0.000	0.9826	yes
1993–2004	0.4982	–0.0072	57.86	–6.13	0.000	0.000	0.7898	yes
2004–2015	0.3858	–0.0123	61.67	–14.52	0.000	0.000	0.9547	yes
2015–2025	0.2505	–0.0113	54.06	–16.55	0.000	0.000	0.9682	yes

Notes: α_0 and α_1 – parameters in the regression equation (respectively: constant and slope), t – *t*-student statistic, p – significance level (*p-value*), R^2 – coefficient of determination.

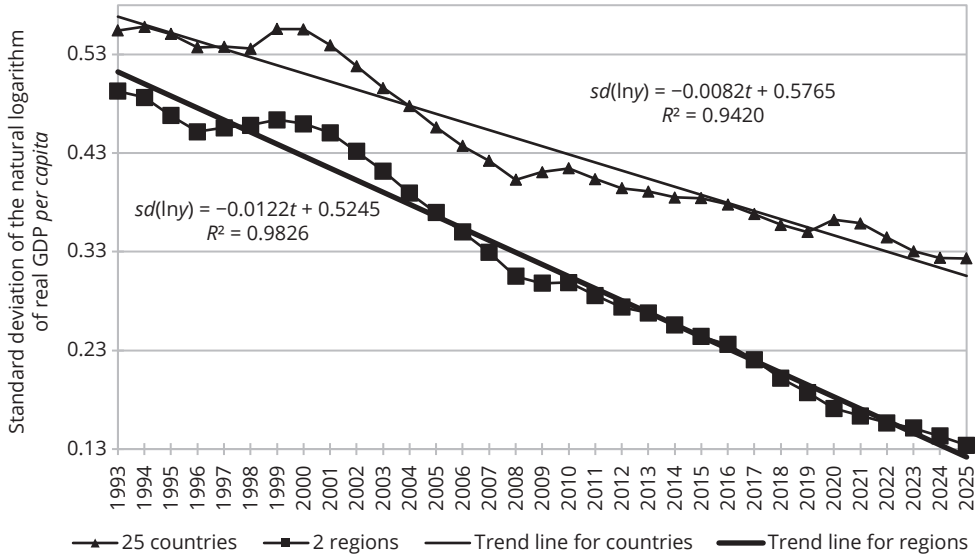
Source: own elaboration based on IMF data.

The data in Table 5.2 shows that σ-convergence occurred over the whole 1993–2025 period, both among the EU-25 and between the EU-11 and EU-14 areas. The slopes of both estimated trend lines are negative and statistically significant at very high significance levels (*p*-values equal to 0.000 indicate that the *p*-value parameter is less than 0.0005). The high values of the coefficients of determination (over 90%) indicate a very strong fit between the empirical observations and the estimated trend lines.

Figure 5.4 shows the trend in the standard deviation of the logarithms of GDP *per capita*. As can be seen, the income gap between the new and old EU countries generally exhibited a decreasing trend. Income disparities declined most visibly and consistently during the second part of the analysed period, i.e. from 2000 onwards. In 2009 and 2010, as a result of the global financial crisis and the weakening of GDP growth in many previously fast-growing economies, income disparities among the 25 countries in the study group widened. Divergence in the EU-25 group also occurred

in 2020 as a consequence of the COVID-19 pandemic, although data averaged over both analysed areas does not confirm this.

Figure 5.4. Standard deviation of GDP *per capita* in 1993–2025



Notes: *sd*(ln*y*) – standard deviation of the natural logarithms of real GDP *per capita* at PPP, *t* – time, R^2 – coefficient of determination.

Source: own elaboration based on IMF data.

Comparing our findings with those of other studies, it should be noted that there is a vast amount of empirical studies on the phenomenon of convergence, making it impossible to list them all here. For a detailed review of empirical studies, see, *inter alia*, Matkowski, Rapacki and Próchniak [2016b]. The books by Malaga [2004], Michałek, Siwiński and Socha [2007], Liberda [2009], Batóg [2010], Próchniak and Witkowski [2016], Jóźwik [2017] and Kotliński and Warżała [2020] are either entirely or largely devoted to the phenomenon of convergence in EU or OECD countries. In turn, the books by Wojcik [2018] and Bernardelli, Próchniak and Witkowski [2021] present several novel approaches to measuring convergence, together with extensive empirical analysis.

It should also be noted that studies suggesting the possibility of divergence in Europe (both at the national and regional level) are common. For example, Mucha [2012] suggests that for some Eurozone countries, having a common currency may generate numerous problems and cause the emergence of economic divergence from other members of the economic and monetary union. Monfort, Cuestas and Ordóñez [2013] analyse the real convergence of GDP per worker in 23 EU countries over the period

1980–2009 (Western European countries) and 1990–2009 (CEE countries). Applying club convergence survey techniques (i.e. convergence in subgroups of countries), they find strong evidence supporting the claim of EU-wide divergence in income *per capita*, even though, for example, CEE countries (excluding the Czech Republic but including Greece) form a converging group. Borsi and Metiu [2013] analyse real convergence among the 27 EU countries over the period 1970–2010, concluding that there is no convergence in income *per capita* levels across the group and that convergence occurs only in subgroups of countries moving towards different steady states. Stanišić [2012] analyses β-convergence in the EU-25 and within two groups of countries: the EU-15 and the EU-10, confirming the occurrence of β-convergence in the EU-25 countries (implying convergence of new EU member states towards Western Europe) and denying the occurrence of convergence within the EU-15 and EU-10 groups. The author further argues that income disparities between the EU-25 countries increased during the global financial crisis, although the extent and temporal scope of this increase were limited and did not affect the long-term convergence path. This conclusion is very similar to the results of our study.

As can be seen, the convergence process does not occur automatically. Despite the strong trend of narrowing income disparities between CEE and Western Europe in recent years, there is no guarantee that this will continue in the future, as evidenced by the temporal instability of the results obtained and the increasing references in the literature to the possibility of divergence trends in Europe. An extremely important task for economic policymakers is therefore to take such a course of action as to maintain the current long-term trends of economic growth in Europe, marked by decreasing income disparities between the eastern and western areas of the continent.

5.4. Conclusions

In the countries of the enlarged EU, income convergence in terms of β-convergence could be observed throughout the period 1993–2025. It occurred both among the 25 countries in the study group and between the two areas (EU-11 and EU-14). Across the EU-25 countries, the rate of economic growth between 1993 and 2025 was negatively correlated with the initial level of GDP *per capita*. The new EU Member States from the CEE region achieved faster economic growth rates than Western European countries, even though the initial level of GDP *per capita* in the former was much lower.

The β coefficients, which measure the rate of the convergence process, amounted to 1.78% for the group of 25 countries and 2.30% for the two analysed areas. This implies that, assuming the average economic growth trend of 1993–2025 is maintained, the

countries of the enlarged EU will require approx. 30–40 years to halve the gap relative to a common hypothetical long-run equilibrium state.

The rate of convergence was very different in the sub-periods identified. This was due to the occurrence of crisis events, such as the global financial crisis, the COVID-19 pandemic, and the war in Ukraine, as well as the impact of various institutional factors on economic growth, e.g. those related to EU membership. Nevertheless, convergence was observed in all the sub-periods identified.

σ-convergence was also observed over the entire 1993–2025 period, both among the EU-25 and between the two analysed areas (EU-11 and EU-14). Income disparities declined most visibly and consistently in the second part of the analysed period, i.e. from 2000 onwards. In 2009 and 2010, as a result of the global financial crisis and the weakening of GDP growth in many countries that had been growing fast so far, income disparities within the EU-25 widened. Divergence within this group of countries also occurred in 2020 as a consequence of the COVID-19 pandemic.

Therefore, a reduction in the differences in competitiveness, as measured by the level of economic development of the old and new EU Member States, cannot be unconditionally expected in the short term. The acceleration of the convergence process will depend, *inter alia*, on sound economic policies aimed at reducing the development gap between the CEE countries and Western Europe. The war in Ukraine and the energy crisis will also have a significant impact on future economic growth, as they entail the danger of a significant weakening of convergence and even the emergence of divergent tendencies in the future. It is to be hoped, however, that such a pessimistic scenario will not materialise and that the CEE countries will continue on their path of rapid economic growth and closing the further reduction of the development gap relative to Western Europe.

References

Batóg, J. (2010). *Konwergencja dochodowa w krajach Unii Europejskiej*. Szczecin: Wydawnictwo Naukowe Uniwersytetu Szczecińskiego.

Bernardelli, M., Próchniak, M., Witkowski, B. (2021). *Economic Growth and Convergence. Global Analysis Through Econometric and Hidden Markov Models*. London – New York: Routledge.

Borsi, M.T., Metiu, N. (2013). *The Evolution of Economic Convergence in the European Union* (Discussion Paper No. 28). Deutsche Bundesbank, https://www.bundesbank.de/resource/blob/703768/872d6502302785e08312710075aff44a/472B63F073F071307366337C94F8C870/2013-08-13-dkp-28-data.pdf (accessed: 20.10.2025).

Eurostat (2025). *Database*, https://ec.europa.eu/eurostat (accessed: 20.10.2025).

IMF (2025). *World Economic Outlook Database. October 2025*, https://data.imf.org/en/datasets/IMF.RES:WEO (accessed: 16.10.2025).

Jóźwik, B. (2017). *Realna konwergencja gospodarcza państw członkowskich Unii Europejskiej z Europy Środkowej i Wschodniej. Transformacja, integracja i polityka spójności*. Warszawa: Wydawnictwo Naukowe PWN.

Kotliński, K., Warżała, R. (2020). *Euro a proces konwergencji państw Europy Środkowo-Wschodniej. Próba oceny*. Olsztyn: Instytut Badań Gospodarczych. DOI: 10.24136/eep.mon.2020.11.

Liberda, Z.B. (2009). *Konwergencja gospodarcza Polski*. Warszawa: PTE.

Malaga, K. (2004). *Konwergencja gospodarcza w krajach OECD w świetle zagregowanych modeli wzrostu*. Poznań: Wydawnictwo Akademii Ekonomicznej.

Mankiw, N.G., Romer, D., Weil, D.N. (1992). A Contribution to the Empirics of Economic Growth, *The Quarterly Journal of Economics*, 107, pp. 407–437. DOI: 10.2307/2118477.

Matkowski, Z., Próchniak, M. (2013). Real Income Convergence. In: *Poland. Competitiveness Report 2013. National and Regional Dimensions* (pp. 44–64), M.A. Weresa (Ed.). Warsaw: SGH Publishing House.

Matkowski, Z., Rapacki, R., Próchniak, M. (2016a). Income Convergence in Poland vis-à-vis the EU: Major Trends and Prospects. In: *Poland. Competitiveness Report 2016. The Role of Economic Policy and Institutions* (pp. 37–55), M.A. Weresa (Ed.). Warsaw: SGH Publishing House.

Matkowski, Z., Rapacki, R., Próchniak, M. (2016b). Real Income Convergence Between Central Eastern and Western Europe: Past, Present, and Prospects, *Ekonomista*, 6, pp. 853–892.

Michałek, J.J., Siwiński, W., Socha, M. (2007). *Polska w Unii Europejskiej – dynamika konwergencji ekonomicznej*. Warszawa: Wydawnictwo Naukowe PWN.

Monfort, M., Cuestas, J.C., Ordóñez, J. (2013). Real Convergence in Europe: A Cluster Analysis, *Economic Modelling*, 33, pp. 689–694. DOI: 10.1016/j.econmod.2013.05.015.

Mucha, M. (2012). Mechanizm dywergencji gospodarczej w strefie euro, *Ekonomista*, 4, pp. 487–498.

Próchniak, M. (2017). Income Convergence Between the CEE Region and Western Europe. In: *Poland. Competitiveness Report 2017. Internationalization and Poland's Competitive Position* (pp. 29–40), M.A. Weresa (Ed.). Warsaw: SGH Publishing House.

Próchniak, M. (2022). Poland's Income Convergence Towards the EU Average. In: *Poland. Competitiveness Report 2022. Towards a Sustainable Economy in a Pandemic Era* (pp. 155–169), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M. (2023). Income Convergence in the European Union and the Pentagon of Competitiveness. In: *Poland. Competitiveness Report 2023. Focus on Entrepreneurship and Competitive Advantages* (pp. 43–62), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M. (2024). Income Convergence in the European Union and the Pentagon of Competitiveness. In: *Poland. Competitiveness Report 2024. The Role of Public Health in Creating Competitive Advantages* (pp. 29–47), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M. (2025). Income Convergence: Poland in the European Union – the Pentagon of Competitiveness. In: *Poland. Competitiveness Report 2025. Reconfiguring Global Value Chains and Shaping Competitive Advantages* (pp. 77–97), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M., Lissowska, M., Maszczyk, P., Rapacki, R., Sulejewicz, A. (2019). Wyrównywanie luki w poziomie zamożności między Europą Środkowo-Wschodnią a Europą Zachodnią. In: *Europa Środkowo-Wschodnia wobec globalnych trendów: gospodarka, społeczeństwo i biznes* (pp. 13–43), M. Strojny (Ed.). Warszawa: Oficyna Wydawnicza SGH.

Próchniak, M., Witkowski, B. (2012). *Real Economic Convergence and the Impact of Monetary Policy on Economic Growth of the EU Countries: The Analysis of Time Stability and the Identification of Major Turning Points Based on the Bayesian Methods* (Working Paper No. 137). National Bank of Poland, https://static.nbp.pl/publikacje/materialy-i-studia/137_en.pdf (accessed: 20.10.2025).

Próchniak, M., Witkowski, B. (2016). *Konwergencja dochodowa typu beta w ujęciu teoretycznym i empirycznym*. Warszawa: Oficyna Wydawnicza SGH.

Rapacki, R., Maszczyk, P., Lissowska, M., Próchniak, M., Sulejewicz, A. (2025). Patchwork Capitalism and Economic Development Trajectories of CEE11 Countries in 2004–2022, *Eastern European Economics*, 63(6), pp. 845–874. DOI: 10.1080/00128775.2025.2499043.

Rapacki, R., Próchniak, M. (2012). Wzrost gospodarczy w krajach Europy Środkowo-Wschodniej na tle wybranych krajów wschodzących, *Gospodarka Narodowa. The Polish Journal of Economics*, 253(1–2), pp. 65–96. DOI: 10.33119/GN/101018.

Rapacki, R., Próchniak, M. (2019). EU Membership and Economic Growth: Empirical Evidence for the CEE Countries, *The European Journal of Comparative Economics*, 16(1), pp. 3–40. DOI: 10.25428/1824-2979/201901-3-40.

Solow, R.M. (1956). A Contribution to the Theory of Economic Growth, *The Quarterly Journal of Economics*, 70(1), pp. 65–94. DOI: 10.2307/1884513.

Stanišić, N. (2012). The Effects of the Economic Crisis on Income Convergence in the European Union, *Acta Oeconomica*, 62(2), pp. 161–182. DOI: 10.1556/aoecon.62.2012.2.2.

Wójcik, P. (2018). *Metody pomiaru realnej konwergencji gospodarczej w ujęciu regionalnym i lokalnym. Konwergencja równoległa*. Warszawa: Wydawnictwa Uniwersytetu Warszawskiego.

Chapter 6

Changes in Total Factor Productivity in the Context of Research and Development

Mariusz Próchniak

6.1. Introduction

The aim of this chapter is to determine the pace of technological progress in relation to research and development expenditure. Since technological progress is extremely difficult to measure, we will estimate it using total factor productivity (TFP).

Total factor productivity will be analysed using growth accounting. Growth accounting is the empirical study used to determine how much economic growth results from changes in measurable factors of production and how much is attributable to changes in the level of technical development, as measured by the growth rate of total factor productivity.

The analysis covers 11 Central and Eastern European (CEE) countries, i.e. the EU-11 group (Poland, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Slovakia and Slovenia) over the period 2015–2024. In order to assess the dynamics of changes in total factor productivity during the period under study, we also present average TFP growth rates for the following two sub-periods: 2015–2019 (i.e. before the outbreak of the COVID-19 pandemic) and 2021–2025 (i.e. after the coronavirus pandemic).[1]

This study builds on earlier research in this field presented in previous editions of the *Competitiveness Report* [see, e.g., Próchniak, 2022, 2023, 2024, 2025]. In the 2020 edition of the report [Próchniak, 2020], sector-level economic growth accounting was additionally undertaken.

An important novelty in this year's study is the extension of the growth accounting framework to include research and development (R&D) as a factor of competitive

[1] The year 2020 has not been included in any of the subperiods, as it is the year in which the pandemic occurred, while the comparison we want to make concerns the period before and after the outbreak of the pandemic. Therefore, from a substantive point of view, the inclusion of 2020 in the analysis does not fit into either of the two identified time periods.

advantage, in line with the main theme of the *Report*. R&D expenditure has a significant impact on technological progress in a country. An increase in such expenditure is typically associated with greater innovation and faster technological progress, although this relationship is not universal and depends on the effectiveness of the expenditure itself. Nevertheless, TFP, as an approximate measure of technological progress, depends to a large extent on R&D expenditure. Therefore, in this edition of the study, we are expanding the growth accounting framework by adding a third factor of production, which can be described as technological know-how or technological capital,[2] dependent on R&D expenditure. As a result, we will estimate what proportion of TFP is attributable to R&D activities and what proportion is residual, i.e. the result of the impact of other factors not included in the growth accounting framework.

6.2. The standard growth accounting framework: theoretical foundations

The origins of growth accounting date back to the first half of the 20th century. The concept of total productivity and the recognition that labour is not the only factor of production, and that other factors such as capital and land should be taken into account when measuring the wealth of nations and productivity, were discussed in the economic literature in the 1930s [Griliches, 1996]. The first references to an input – output type indicator appeared in Copeland's 1937 work [Griliches, 1996]. In the 1940s and 1950s, a number of – largely independent – studies were published with the results of empirical studies on the measurement of TFP. The first such study, conducted by the Dutch economist Jan Tinbergen, was published in 1942. In the following years, further works were written examining the relationship between the volume of production and the inputs incurred [see, e.g., Tintner, 1944; Barton, Cooper, 1948; Johnson, 1950; Schmookler, 1952; Abramovitz, 1956; Kendrick, 1956; Ruttan, 1956].

The first economist to formalise growth accounting was Robert Solow [1957]. Using a macroeconomic production function and differential calculus, he demonstrated how the rate of economic growth can be decomposed into the part resulting from increased inputs of factors of production and the remaining part, the so-called Solow residual. The latter indicates what proportion of economic growth cannot be attributed to individual factors. It therefore constitutes a measure of technological progress, i.e. TFP growth.

[2] The expansion of the growth accounting framework is inspired by the approach proposed by Nonneman and Vanhoudt [1996]. The cited authors extended Solow's model by incorporating an arbitrary number of factors of production and used it to conduct an empirical study using three factors of production: tangible capital, human capital and technological know-how.

In subsequent years, further studies on growth accounting were published, introducing innovative approaches and extensions to earlier research and incorporating new elements of empirical analysis [see, e.g., Solow, 1962; Griliches, 1964; Jorgenson, Griliches, 1967].

The decomposition of economic growth pioneered by Solow forms the basis of modern growth accounting. The starting point for such an analysis is the macroeconomic production function, which in its general form can be written as follows:

$$Y(t) = F\big(A(t), Z_1(t), \ldots, Z_n(t)\big), \tag{6.1}$$

where Y – production (GDP), A – level of technology, Z_1, …, Z_n – measurable factors of production.

Empirical studies usually include two or three measurable factors of production, namely labour, tangible (physical) capital, and, in some cases, human capital.

The standard growth accounting framework takes into account two measurable factors of production: labour and tangible capital.[3] The production function (6.1), therefore, takes the following form:

$$Y(t) = F\big(A(t), L(t), K(t)\big). \tag{6.2}$$

In order to decompose the economic growth rate into its individual components, equation 6.2 needs to be transformed to represent the growth rate Y. This is achieved by differentiating it with respect to time and then dividing by Y. The result is:

$$\frac{\dot{Y}}{Y} = \frac{\frac{\partial F(A,L,K)}{\partial A}\dot{A}}{Y} + \frac{\frac{\partial F(A,L,K)}{\partial L}\dot{L}}{Y} + \frac{\frac{\partial F(A,L,K)}{\partial K}\dot{K}}{Y}. \tag{6.3}$$

After multiplying the individual components on the right-hand side of equation 6.3 by A/A, L/L and K/K respectively, we obtain:

$$\frac{\dot{Y}}{Y} = \frac{\frac{\partial F(A,L,K)}{\partial A}A}{Y}\frac{\dot{A}}{A} + \frac{\frac{\partial F(A,L,K)}{\partial L}L}{Y}\frac{\dot{L}}{L} + \frac{\frac{\partial F(A,L,K)}{\partial K}K}{Y}\frac{\dot{K}}{K}. \tag{6.4}$$

[3] In the 2012 and 2014 editions of the study, in addition to the basic growth accounting model, an extended model including human capital was also estimated [Próchniak, 2012, 2014].

Equation 6.4 shows that the GDP growth rate is a weighted average of the growth rates of three factors: technology, labour and tangible capital. The weights correspond to the shares of each factor in GDP, measured as the marginal product of the factor (at the level of the whole economy) multiplied by the quantity of the factor and divided by the volume of production.

In order to calculate the growth rate of TFP in an empirical analysis, additional assumptions need to be introduced into equation 6.4, which constitute the core of the growth accounting framework.

We assume, firstly, that the production function is characterised by Hicks-neutral technological progress. Accordingly, the function can be written as follows:

$$F(A,L,K) = A \cdot f(L,K). \tag{6.5}$$

As can be seen, Hicks-neutral technological progress implies that the variable A, representing the level of technology, appears in the product of production function f, leaving the volume of production dependent on the inputs of measurable factors. Technological progress contributes equally to both factors of production, without changing the marginal rate of technical substitution between them. For production function (6.5), the technology income share, i.e. the component $(\partial F/\partial A)\ A/Y$ in equation 6.4, is 1. Equation 6.4 can then be written as:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\frac{\partial F\left(A,L,K\right)}{\partial L} L}{Y} \frac{\dot{L}}{L} + \frac{\frac{\partial F\left(A,L,K\right)}{\partial K} K}{Y} \frac{\dot{K}}{K}. \tag{6.6}$$

The above equation shows that the rate of economic growth is the sum of technological progress (TFP growth) and the weighted average growth rate of the stock of labour and tangible capital, where the weights correspond to the income shares of both factors.

An additional assumption must also be made regarding the marginal products of the two factors. The marginal products of labour and capital at the level of the entire economy are, in practice, unmeasurable. We therefore assume that all markets are perfectly competitive and that there are no externalities. Under these assumptions, the marginal product of capital $\partial F/\partial K$ is equal to the price of capital r, while the marginal product of labour $\partial F/\partial L$ corresponds to the wage rate w. Denoting by s_K the capital income share (rK/Y) and by s_L the labour income share (wL/Y), equation 6.6 can be written as follows:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + s_K \frac{\dot{K}}{K} + s_L \frac{\dot{L}}{L}. \tag{6.7}$$

Let us make the additional assumption that all income can be attributed to one of two factors of production: labour or tangible capital, i.e.: $Y = wL + rK$ (where wL denotes total labour income in the economy, while rK denotes total capital income). Under this assumption, the labour income share and the tangible capital income share sum to unity: $s_K + s_L = 1$. Thus, formula 6.7 takes the following form:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + s_K \frac{\dot{K}}{K} + \left(1 - s_K\right)\frac{\dot{L}}{L}. \tag{6.8}$$

Equation 6.8 forms the basis of standard growth accounting. It can be used to calculate the TFP growth rate as the difference between the GDP growth rate and the weighted average growth rate of the two production factors:

$$\text{TFP growth} = \frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \left[s_K \frac{\dot{K}}{K} + \left(1 - s_K\right)\frac{\dot{L}}{L} \right]. \tag{6.9}$$

6.3. Augmented growth accounting framework

As noted in the introduction, this edition of the study incorporates technological capital as a factor that largely explains technological progress. We assume that TFP is determined partly by the level of technological capital and partly by other factors, which in this case constitute the residual component. This residual will be referred to as corrected TFP (TFP_{corr}). Corrected TFP is a residual measure and, from an economic perspective, better reflects total factor productivity, as it excludes the component of TFP changes attributable to research and development expenditure. In other words, it takes into account the total productivity resulting from the interaction between the production factors, while also measuring the impact of other elements not included in the model.

Let us denote the level of technological capital (technological know-how) by T. Consequently, TFP can be expressed as the product of this capital and corrected TFP, according to the following equation:

$$A \equiv TFP = T \times TFP_{corr}. \tag{6.10}$$

After taking the logarithm of equation 6.10 and differentiating it with respect to time, we obtain:

$$\frac{\dot{TFP}}{TFP} = \frac{\dot{T}}{T} + \frac{\dot{TFP}_{corr}}{TFP_{corr}}. \tag{6.11}$$

Formula 6.11 shows that the growth rate of TFP is equal to the sum of the growth rate of technological capital and the growth rate of corrected TFP. Substituting formula 6.11 into equation 6.9, we obtain:

$$\frac{\dot{TFP}_{corr}}{TFP_{corr}} = \frac{\dot{TFP}}{TFP} - \frac{\dot{T}}{T} = \frac{\dot{Y}}{Y} - \left[S_K \frac{\dot{K}}{K} + (1 - S_K) \frac{\dot{L}}{L} \right] - \frac{\dot{T}}{T}. \tag{6.12}$$

Equation 6.12 forms the basis of the augmented growth accounting framework. It will be used to calculate the growth rate of corrected TFP.

6.4. Results of the empirical study

For the purposes of the analysis, data was collected to form the following time series:

a) economic growth rate,
b) rate of change in labour input,
c) rate of change in tangible capital input,
d) rate of change in technological capital input.

The economic growth rate is measured as the annual growth rate of real total GDP, determined on the basis of data from the International Monetary Fund database [IMF, 2025]. The labour input growth rate is measured using employment dynamics reported by the International Labour Organisation [ILO, 2025]. The time series of the tangible capital stock is calculated using the perpetual inventory method based on data from the World Bank [World Bank, 2025].

This method requires several assumptions to be made. We assume a depreciation rate of 5% and the initial capital/production ratio of 3. In the perpetual inventory method, the starting year should slightly precede the years for which TFP is calculated; accordingly, in our study, the calculations begin in 2000, which is the year for which the tangible capital/production ratio is assumed to be 3. A variable expressing gross fixed capital formation is used as the measure of investment. The income shares of labour and tangible capital in income are 0.5.[4]

[4] Some studies assume arbitrary factor income shares [see, e.g., King, Levine, 1994; Wang, Yao, 2003; Caselli, Tenreyro, 2005]. Wang and Yao [2003] demonstrate that the factor income shares, determined at different levels, do not significantly affect the results obtained. Caselli and Tenreyro [2005] reach similar conclusions based on models using both arbitrary and actual factor income shares. In the literature, it is most commonly assumed that the income share of tangible capital is 0.3. However, for some countries (especially Poland), an income share of tangible capital of 0.3 significantly overestimates the TFP growth

Estimating the rate of change in the stock of technological capital poses a certain research challenge. By its very nature, this variable is difficult to measure. However, it can be assumed that the dynamics of technological capital depend on expenditure allocated to its accumulation. Research and development expenditure provides a good measure of such outlays. Of course, this is not the only factor contributing to the creation of technological capital. Furthermore, R&D activities may be conducted ineffectively and therefore may not contribute to an increase in the level of technology. Nevertheless, it seems justified to treat R&D expenditure as a measure of investment in technological capital.

As a result, in this study we calculate the dynamics of the technological capital stock in a manner very similar to the method used to estimate the dynamics of the tangible capital stock. Starting from the initial year, for which the ratio of technological capital to production is assumed to be 3 (the exact value is not particularly important in this case), we use the perpetual inventory method. However, unlike in the case of tangible capital, the variable contributing to the accumulation of technological capital is not investment expenditure but R&D expenditure. We use the variable "gross domestic expenditure on R&D" (GERD) derived from Eurostat data [2025]. At the same time, we assume that technological capital does not depreciate (i.e. the depreciation rate is equal to 0%).

In this edition of the study, all the time series of the variables analysed have been updated, meaning that the calculations presented have been performed anew. Consequently, this study provides full documentation of the results without duplicating the information contained in previous editions of the *Report*.

Table 6.1 presents the detailed results of the economic growth decomposition, while Tables 6.2 and 6.3 summarise the data from Table 6.1.

Between 2015 and 2024, the group of CEE countries recorded a TFP growth rate of 1.2% per year (unweighted average). Half of the TFP growth was driven by R&D activities, and, as a result, the average growth rate of corrected TFP for the EU-11 group as a whole amounted to 0.6%. Croatia exhibited the fastest productivity growth rate over the period under review (2.2%), while Bulgaria and Romania shared second place (2.0%). Slovenia ranked fourth (1.9%), and Poland ranked fifth (1.7%). A negative rate of change in TFP was recorded only in Estonia (–0.6%). The ranking of individual countries in terms of corrected TFP is similar: Croatia and Romania recorded the fastest growth over the period 2015–2024 (1.7% each), followed by Bulgaria, Slovenia and Poland.

rate. Therefore, as suggested by Welfey [see, e.g., 2001], this share was increased to 0.5, which more accurately reflects the actual data.

Table 6.1. Contributions of labour, tangible capital, standard TFP and R&D-corrected TFP to economic growth, 2015–2024

	Specification	2015			2016			2017			2018			2019			2020			2021			2022			2023			2024		
		growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)
Bulgaria	L	1.7	0.8	25	−0.5	−0.2	−8	4.4	2.2	81	0.1	0.0	2	−3.4	−1.7	−45	−3.7	−1.8	57	−1.9	−0.9	−12	2.2	1.1	27	−0.3	−0.1	−8	0.0	0.0	1
	K	2.2	1.1	32	2.2	1.1	37	1.6	0.8	29	1.7	0.8	33	1.9	1.0	26	2.1	1.1	−33	2.0	1.0	13	1.3	0.7	16	1.6	0.8	43	2.2	1.1	39
	TFP	1.5	1.5	43	2.2	2.2	72	−0.3	−0.3	−10	1.7	1.7	65	4.5	4.5	120	−2.4	−2.4	76	7.7	7.7	99	2.3	2.3	57	1.2	1.2	65	1.7	1.7	61
	K_T	0.4	–	–	0.5	–	–	0.4	–	–	0.4	–	–	0.4	–	–	0.5	–	–	0.5	–	–	0.5	–	–	0.5	–	–	0.5	–	–
	TFP_{corr}	1.0	1.0	31	1.7	1.7	55	−0.7	−0.7	−25	1.2	1.2	49	4.1	4.1	108	−2.9	−2.9	91	7.2	7.2	93	1.8	1.8	45	0.7	0.7	39	1.2	1.2	42
	GDP	3.4	3.4	100	3.0	3.0	100	2.7	2.7	100	2.5	2.5	100	3.8	3.8	100	−3.2	−3.2	100	7.8	7.8	100	4.0	4.0	100	1.9	1.9	100	2.8	2.8	100
Croatia	L	1.0	0.5	21	−0.4	−0.2	−5	1.0	0.5	15	0.8	0.4	14	0.9	0.4	14	−1.5	−0.8	9	1.3	0.6	5	1.4	0.7	10	0.8	0.4	12	3.9	2.0	50
	K	0.4	0.2	9	0.9	0.5	13	1.1	0.6	17	1.2	0.6	20	1.4	0.7	22	2.1	1.0	−12	1.5	0.7	6	1.7	0.9	12	2.3	1.1	34	2.8	1.4	36
	TFP	1.6	1.6	69	3.2	3.2	92	2.2	2.2	67	1.9	1.9	66	2.0	2.0	64	−8.6	−8.6	103	11.2	11.2	89	5.7	5.7	78	1.8	1.8	53	0.5	0.5	14
	K_T	0.3	–	–	0.3	–	–	0.4	–	–	0.4	–	–	0.4	–	–	0.5	–	–	0.5	–	–	0.6	–	–	0.7	–	–	0.7	–	–
	TFP_{corr}	1.3	1.3	56	2.9	2.9	83	1.8	1.8	56	1.6	1.6	54	1.6	1.6	51	−9.1	−9.1	109	10.7	10.7	85	5.1	5.1	70	1.1	1.1	32	−0.2	−0.2	−4
	GDP	2.3	2.3	100	3.5	3.5	100	3.3	3.3	100	2.9	2.9	100	3.1	3.1	100	−8.3	−8.3	100	12.6	12.6	100	7.3	7.3	100	3.3	3.3	100	3.9	3.9	100
Czech Republic	L	1.4	0.7	14	1.9	1.0	37	1.6	0.8	16	1.4	0.7	24	0.2	0.1	2	−1.3	−0.6	12	−0.3	−0.2	−4	−1.0	−0.5	−17	−2.1	−1.0	−2186	2.6	1.3	105
	K	2.1	1.1	21	2.6	1.3	50	2.2	1.1	22	2.3	1.1	40	2.8	1.4	39	3.1	1.6	−29	2.5	1.2	31	2.8	1.4	49	3.1	1.5	3196	3.0	1.5	123
	TFP	3.2	3.2	65	0.3	0.3	13	3.2	3.2	63	1.0	1.0	35	2.1	2.1	59	−6.2	−6.2	117	2.9	2.9	73	1.9	1.9	68	−0.4	−0.4	−910	−1.6	−1.6	−128
	K_T	0.8	–	–	0.9	–	–	0.8	–	–	0.8	–	–	0.9	–	–	1.0	–	–	0.9	–	–	0.9	–	–	0.9	–	–	0.9	–	–
	TFP_{corr}	2.4	2.4	48	−0.5	−0.5	−20	2.5	2.5	48	0.2	0.2	6	1.2	1.2	33	−7.2	−7.2	135	2.0	2.0	50	1.0	1.0	35	−1.4	−1.4	−2856	−2.5	−2.5	−200
	GDP	5.0	5.0	100	2.6	2.6	100	5.2	5.2	100	2.8	2.8	100	3.6	3.6	100	−5.3	−5.3	100	4.0	4.0	100	2.8	2.8	100	0.0	0.0	100	1.2	1.2	100
Estonia	L	1.3	0.6	35	0.9	0.5	15	1.8	0.9	16	1.0	0.5	13	0.9	0.4	12	−2.3	−1.2	40	1.1	0.6	7	4.1	2.0	−166	2.8	1.4	−51	0.5	0.3	−303
	K	3.0	1.5	82	2.5	1.3	41	2.7	1.4	24	3.6	1.8	48	4.1	2.1	56	4.3	2.2	−75	5.5	2.8	34	5.0	2.5	−204	3.8	1.9	−68	4.1	2.0	−2261
	TFP	−0.3	−0.3	−17	1.4	1.4	44	3.4	3.4	60	1.4	1.4	39	1.2	1.2	33	−3.9	−3.9	135	4.9	4.9	60	−5.8	−5.8	470	−6.0	−6.0	220	−2.4	−2.4	2664
	K_T	0.7	–	–	0.7	–	–	0.6	–	–	0.7	–	–	0.8	–	–	0.9	–	–	1.0	–	–	1.0	–	–	1.0	–	–	1.0	–	–
	TFP_{corr}	−1.0	−1.0	−55	0.6	0.6	20	2.7	2.7	48	0.8	0.8	20	0.4	0.4	12	−4.8	−4.8	167	3.9	3.9	48	−6.8	−6.8	555	−7.1	−7.1	258	−3.4	−3.4	3811
	GDP	1.8	1.8	100	3.1	3.1	100	5.6	5.6	100	3.7	3.7	100	3.7	3.7	100	−2.9	−2.9	100	8.3	8.3	100	−1.2	−1.2	100	−2.7	−2.7	100	−0.1	−0.1	100
Hungary	L	2.7	1.3	37	3.4	1.7	69	1.6	0.8	19	0.9	0.4	8	0.8	0.4	8	−1.4	−0.7	17	4.2	2.1	29	1.4	0.7	17	0.6	0.3	−36	0.1	0.0	8
	K	2.0	1.0	28	2.2	1.1	46	1.3	0.7	16	2.5	1.2	22	3.5	1.8	35	4.3	2.1	−49	3.2	1.6	22	3.4	1.7	40	3.2	1.6	−191	2.3	1.2	229
	TFP	1.3	1.3	36	−0.4	−0.4	−15	2.6	2.6	64	3.9	3.9	70	2.9	2.9	57	−5.8	−5.8	133	3.5	3.5	48	1.8	1.8	43	−2.7	−2.7	326	−0.7	−0.7	−137
	K_T	0.6	–	–	0.6	–	–	0.5	–	–	0.6	–	–	0.7	–	–	0.7	–	–	0.7	–	–	0.8	–	–	0.7	–	–	0.7	–	–
	TFP_{corr}	0.7	0.7	20	−0.9	−0.9	−38	2.1	2.1	52	3.3	3.3	60	2.2	2.2	43	−6.5	−6.5	149	2.8	2.8	38	1.0	1.0	24	−3.5	−3.5	411	−1.4	−1.4	−274
	GDP	3.7	3.7	100	2.4	2.4	100	4.1	4.1	100	5.6	5.6	100	5.1	5.1	100	−4.3	−4.3	100	7.2	7.2	100	4.3	4.3	100	−0.8	−0.8	100	0.5	0.5	100

	Specification	2015			2016			2017			2018			2019			2020			2021			2022			2023			2024		
		growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)	growth (%)	contribution (p.p.)	contribution (%)
Latvia	L	1.3	0.6	17	−0.3	−0.2	−6	0.2	0.1	3	1.6	0.8	19	0.1	0.0	5	−1.9	−0.9	27	−2.6	−1.3	−19	2.5	1.2	69	−0.1	−0.1	−3	−0.7	−0.4	80
	K	2.1	1.0	28	1.7	0.9	34	1.2	0.6	18	1.8	0.9	21	2.5	1.2	182	2.4	1.2	−34	2.0	1.0	15	2.4	1.2	65	2.1	1.0	36	2.6	1.3	−295
	TFP	2.1	2.1	55	1.8	1.8	72	2.7	2.7	80	2.6	2.6	60	−0.6	−0.6	−87	−3.7	−3.7	107	7.2	7.2	104	−0.6	−0.6	−34	1.9	1.9	66	−1.4	−1.4	316
	K_T	0.4	–	–	0.4	–	–	0.3	–	–	0.3	–	–	0.4	–	–	0.4	–	–	0.5	–	–	0.5	–	–	0.5	–	–	0.5	–	–
	TFP_{corr}	1.7	1.7	45	1.5	1.5	58	2.5	2.5	72	2.3	2.3	53	−1.0	−1.0	−147	−4.1	−4.1	119	6.8	6.8	98	−1.1	−1.1	−61	1.4	1.4	48	−1.9	−1.9	437
	GDP	3.8	3.8	100	2.6	2.6	100	3.4	3.4	100	4.3	4.3	100	0.7	0.7	100	−3.5	−3.5	100	6.9	6.9	100	1.8	1.8	100	2.9	2.9	100	−0.4	−0.4	100
Lithuania	L	1.2	0.6	21	2.0	1.0	38	−0.5	−0.2	−5	1.5	0.7	15	0.3	0.1	3	−1.5	−0.7	−1532	0.8	0.4	6	3.8	1.9	76	1.4	0.7	167	1.6	0.8	29
	K	2.8	1.4	50	2.9	1.5	56	3.0	1.5	31	3.4	1.7	35	3.9	2.0	42	4.1	2.1	4305	3.9	2.0	31	4.7	2.3	93	4.7	2.4	551	5.1	2.6	94
	TFP	0.8	0.8	29	0.2	0.2	6	3.5	3.5	74	2.4	2.4	49	2.6	2.6	56	−1.3	−1.3	−2673	4.0	4.0	63	−1.7	−1.7	−69	−2.6	−2.6	−618	−0.6	−0.6	−23
	K_T	0.6	–	–	0.6	–	–	0.5	–	–	0.6	–	–	0.6	–	–	0.7	–	–	0.8	–	–	0.8	–	–	0.8	–	–	0.8	–	–
	TFP_{corr}	0.2	0.2	9	−0.5	−0.5	−17	3.0	3.0	63	1.8	1.8	38	2.0	2.0	43	−2.0	−2.0	−4064	3.3	3.3	51	−2.5	−2.5	−100	−3.4	−3.4	−795	−1.4	−1.4	−51
	GDP	2.8	2.8	100	2.6	2.6	100	4.7	4.7	100	4.8	4.8	100	4.7	4.7	100	0.0	0.0	100	6.4	6.4	100	2.5	2.5	100	0.4	0.4	100	2.7	2.7	100
Poland	L	1.6	0.8	18	0.8	0.4	12	1.4	0.7	13	0.3	0.2	3	−0.1	−0.1	−1	−1.7	−0.8	41	3.2	1.6	23	0.5	0.2	5	1.4	0.7	277	1.4	0.7	23
	K	3.2	1.6	36	3.5	1.7	57	2.6	1.3	25	2.5	1.3	20	3.3	1.7	36	3.7	1.8	−90	3.1	1.6	22	3.0	1.5	28	2.9	1.4	578	3.6	1.8	62
	TFP	2.0	2.0	46	0.9	0.9	30	3.2	3.2	62	4.8	4.8	77	3.0	3.0	65	−3.0	−3.0	150	3.8	3.8	54	3.5	3.5	67	−1.9	−1.9	−755	0.4	0.4	14
	K_T	0.5	–	–	0.5	–	–	0.5	–	–	0.6	–	–	0.7	–	–	0.8	–	–	0.8	–	–	0.9	–	–	1.0	–	–	1.1	–	–
	TFP_{corr}	1.5	1.5	35	0.4	0.4	13	2.6	2.6	51	4.2	4.2	68	2.2	2.2	49	−3.9	−3.9	191	2.9	2.9	42	2.6	2.6	49	−2.9	−2.9	−1149	−0.6	−0.6	−22
	GDP	4.4	4.4	100	3.0	3.0	100	5.2	5.2	100	6.2	6.2	100	4.6	4.6	100	−2.0	−2.0	100	6.9	6.9	100	5.3	5.3	100	0.3	0.3	100	2.9	2.9	100
Romania	L	−0.9	−0.5	−14	−1.0	−0.5	−18	2.6	1.3	16	0.2	0.1	2	−0.1	0.0	−1	−1.8	−0.9	25	−9.0	−4.5	−81	0.7	0.3	8	−1.4	−0.7	−29	2.0	1.0	125
	K	3.3	1.6	52	3.5	1.8	61	3.0	1.5	18	3.2	1.6	26	2.8	1.4	36	3.8	1.9	−51	3.4	1.7	31	3.4	1.7	43	3.6	1.8	75	4.5	2.3	277
	TFP	2.0	2.0	63	1.6	1.6	56	5.4	5.4	66	4.4	4.4	72	2.6	2.6	65	−4.6	−4.6	126	8.3	8.3	150	1.9	1.9	48	1.3	1.3	54	−2.5	−2.5	−303
	K_T	0.2	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.3	–	–	0.4	–	–
	TFP_{corr}	1.8	1.8	56	1.3	1.3	47	5.1	5.1	62	4.1	4.1	67	2.2	2.2	57	−5.0	−5.0	135	8.0	8.0	145	1.6	1.6	40	1.0	1.0	41	−2.8	−2.8	−349
	GDP	3.2	3.2	100	2.9	2.9	100	8.2	8.2	100	6.1	6.1	100	3.9	3.9	100	−3.7	−3.7	100	5.5	5.5	100	4.0	4.0	100	2.4	2.4	100	0.8	0.8	100
Slovakia	L	0.0	0.0	0	2.8	1.4	72	1.5	0.8	27	1.4	0.7	18	0.6	0.3	13	−2.1	−1.0	40	1.0	0.5	9	1.9	1.0	218	0.2	0.1	5	0.4	0.2	11
	K	2.5	1.3	25	3.9	1.9	99	2.7	1.4	48	2.5	1.3	31	2.6	1.3	57	2.8	1.4	−54	1.8	0.9	16	2.1	1.0	236	2.2	1.1	51	2.3	1.2	57
	TFP	3.9	3.9	75	−1.4	−1.4	−71	0.7	0.7	25	2.1	2.1	51	0.7	0.7	29	−2.9	−2.9	114	4.3	4.3	75	−1.5	−1.5	−354	1.0	1.0	44	0.7	0.7	32
	K_T	0.5	–	–	0.7	–	–	0.5	–	–	0.5	–	–	0.5	–	–	0.5	–	–	0.6	–	–	0.6	–	–	0.6	–	–	0.7	–	–
	TFP_{corr}	3.4	3.4	66	−2.1	−2.1	−106	0.3	0.3	9	1.5	1.5	38	0.1	0.1	6	−3.5	−3.5	134	3.7	3.7	65	−2.1	−2.1	−489	0.3	0.3	14	0.0	0.0	−1
	GDP	5.2	5.2	100	1.9	1.9	100	2.9	2.9	100	4.1	4.1	100	2.3	2.3	100	−2.6	−2.6	100	5.7	5.7	100	0.4	0.4	100	2.2	2.2	100	2.1	2.1	100
Slovenia	L	0.1	0.0	2	−0.3	−0.1	−4	4.8	2.4	47	2.2	1.1	26	0.2	0.1	3	−0.5	−0.2	6	−0.7	−0.3	−4	1.5	0.7	28	0.3	0.2	7	0.9	0.5	26
	K	0.6	0.3	12	0.5	0.3	8	0.3	0.2	3	0.8	0.4	9	1.4	0.7	19	1.6	0.8	−19	1.0	0.5	6	1.7	0.8	32	1.9	0.9	39	2.0	1.0	57
	TFP	2.1	2.1	86	2.9	2.9	96	2.6	2.6	50	2.9	2.9	65	2.7	2.7	78	−4.7	−4.7	114	8.2	8.2	98	1.1	1.1	40	1.3	1.3	54	0.3	0.3	16
	K_T	0.9	–	–	0.9	–	–	0.8	–	–	0.8	–	–	0.9	–	–	0.9	–	–	0.9	–	–	1.0	–	–	1.0	–	–	1.0	–	–
	TFP_{corr}	1.1	1.1	47	2.0	2.0	67	1.8	1.8	34	2.1	2.1	47	1.9	1.9	53	−5.6	−5.6	137	7.3	7.3	87	0.1	0.1	3	0.3	0.3	13	−0.7	−0.7	−42
	GDP	2.4	2.4	100	3.0	3.0	100	5.2	5.2	100	4.4	4.4	100	3.5	3.5	100	−4.1	−4.1	100	8.4	8.4	100	2.7	2.7	100	2.4	2.4	100	1.7	1.7	100

Source: own elaboration based on data from IMF, ILO, the World Bank, and Eurostat.

Table 6.2. TFP growth rate (%)

Country	The entire 2015–2024 period		The period before the COVID-19 pandemic (2015–2019)		The period after the COVID-19 pandemic (2021–2024)	
	TFP	TFP_{corr}	TFP	TFP_{corr}	TFP	TFP_{corr}
Bulgaria	2.0	1.5	1.9	1.5	3.2	2.7
Croatia	2.2	1.7	2.2	1.8	4.8	4.2
Czech Republic	0.7	–0.2	2.0	1.1	0.7	–0.2
Estonia	–0.6	–1.5	1.4	0.7	–2.3	–3.3
Lithuania	0.7	0.1	1.9	1.3	–0.2	–1.0
Latvia	1.2	0.8	1.7	1.4	1.8	1.3
Poland	**1.7**	**0.9**	**2.8**	**2.2**	**1.5**	**0.5**
Romania	2.0	1.7	3.2	2.9	2.3	1.9
Slovakia	0.7	0.2	1.2	0.7	1.1	0.5
Slovenia	1.9	1.0	2.6	1.8	2.7	1.7
Hungary	0.7	0.0	2.1	1.5	0.5	–0.3
Average*	**1.2**	**0.6**	**2.1**	**1.5**	**1.5**	**0.7**

* Unweighted averages.

Source: own elaboration based on data from IMF, ILO, the World Bank, and Eurostat.

Moving to a more detailed level of analysis and comparing the two identified sub-periods, we can clearly see that the rate of TFP growth in the period before the COVID-19 pandemic, i.e. 2015–2019, was higher than in the post-pandemic period, i.e. 2021–2024. This conclusion applies both to the EU-11 group as a whole and to most of the individual countries. Between 2015 and 2019, the average TFP growth rate in the EU-11 group amounted to 2.1%, which was 0.6 percentage points higher than between 2021 and 2024. At the country level, Estonia, Lithuania, Hungary, the Czech Republic, Poland, Romania and Slovakia achieved faster growth in total factor productivity in the period prior to the pandemic, with Estonia and Lithuania recording the largest differences in this respect (3.7 percentage points and 2.1 percentage points, respectively), largely due to the fact that, in both of these countries, the average TFP growth rate after the pandemic was negative. In Poland, productivity growth reached 2.8% per annum in 2015–2019, compared with 1.5% in 2021–2024.

Similar differences between the two identified time periods are also observed for corrected TFP. For the EU-11 group as a whole, the average annual growth rate of corrected TFP amounted to 1.5% between 2015 and 2019, before declining to 0.7% between 2021 and 2024. In Poland, the growth rate of corrected TFP decreased from 2.2% per annum in 2015–2019 to 0.5% per annum in 2021–2024, i.e. by 1.7 percentage points.

The decline in TFP growth (both overall and corrected) following the outbreak of the pandemic, compared with the years prior to the COVID-19 pandemic, indicates that, in terms of technological progress, the economy has not yet returned to its pre-2020 growth path. Between 2021 and 2024, economic growth was driven to a much greater extent by the accumulation of labour and tangible capital than in the pre-pandemic period. Achieving faster technological progress will constitute a challenge for economic policymakers in terms of sustaining long-term, sustainable economic growth. Further opportunities to increase labour input in the EU-11 countries are limited due to low unemployment rates and increasingly significant barriers to the inflow of cheap labour from abroad. In turn, the accumulation of tangible capital requires a significant increase in capital expenditure, which may prove difficult due, *inter alia*, to the relatively high interest rates associated with the acceleration of inflation in recent years and the need to intensify defence spending. In this context, an important yet challenging task for economic policymakers will be to implement measures aimed at increasing R&D expenditure and accelerating technological progress in the CEE countries.

Poland's results are moderate compared with those of the other new EU Member States. This means that, even taking into account the institutional constraints of the Polish economy resulting from its membership in the CEE cluster and its patchwork model of capitalism,[5] it will be possible within the existing system to implement measures that will accelerate the pace of technological progress. In this context, it is worth highlighting, *inter alia*, the need to intensify and increase R&D expenditure and, more broadly, in the science and education sectors. However, it should be emphasised that it is not only the size of this expenditure that matters, but also its effectiveness. Every expenditure generates demand-side effects, including the multiplier process. In the case of R&D expenditure, however, the key issue concerns supply-side effects, which contribute to an increase in potential output but do not occur automatically. The more effective R&D expenditure is, the stronger the supply-side effects become, which in turn contributes to faster technological progress.

Overall, TFP growth across the EU-11 group was low between 2015 and 2024. Weak performance in this area resulted, primarily, from the sharp decline in total factor productivity in the countries studied in 2020, i.e. during the COVID-19 pandemic. The recession observed at that time in almost all countries led to negative TFP growth rates in 2020. The second factor negatively affecting TFP performance was the outbreak of

[5] The concept of the patchwork model of capitalism, as the model of capitalism found in the new EU Member States, was developed and implemented by a team of economists led by Prof. Ryszard Rapacki from the Warsaw School of Economics [see, e.g., Rapacki et al., 2019; Rapacki, 2019; Maszczyk, Próchniak, Rapacki, 2024; Rapacki et al., 2025].

the war in Ukraine and the associated economic slowdown (and, in some countries, recession), which resulted in negative total factor productivity growth in many EU-11 countries in 2023 and 2024.

We assume in this chapter that the TFP growth is regarded as an approximate measure of technological progress. However, when calculated using the residual TFP method based on growth accounting, it has certain limitations as an indicator of technological progress, which should be borne in mind when interpreting the results. First, the 2020 economic recession, resulting from external factors and not fully reflected in the accumulation of labour and especially capital, which is the result of investment made in earlier years, resulted in a negative estimate of TFP dynamics in 2020. Second, the part of TFP that is the result of increased labour productivity should be partly interpreted as the contribution of human capital to economic growth. Given the difficulties in calculating the stock of this type of capital for the group of countries analysed, TFP in our approach also includes the impact of human capital on economic growth.

When discussing the shortcomings of TFP as a measure of technological progress, it is also worth citing the conclusions of a study conducted by Jasiński [2021], who argues that "TFP is, however, not suitable for assessing the development of innovation or innovativeness, because … technological progress is … treated as a kind of 'residual', whereas this progress currently plays a key role in economic growth. Furthermore, an observed increase or decrease in TFP may indicate a changing role of innovation only indirectly, as it were by implication".

From one year to the next, the leading countries in terms of total factor productivity growth change considerably. This is because growth accounting is a method whose results are strongly dependent on fluctuations in individual variables (labour input, capital input and production volume). These variables (including – particularly output – fluctuate strongly from year to year as a result of economic cycles and irregular fluctuations caused by various demand- and supply-side shocks, both internal and external. Therefore, the ranking of countries in terms of TFP dynamics fluctuates significantly from year to year.

As regards TFP contributions to economic growth, the figures for the period under study are partly distorted, among others due to the fact that when the GDP growth rate is close to 0%, changes in total factor productivity of a few percentage points translate into TFP contribution values reaching several thousand percent (as illustrated, for example, by data for Lithuania from 2020 or for the Czech Republic from 2023). The statistics relating to the TFP contribution to economic growth were also distorted by the COVID-19 pandemic. Nevertheless, some trends and regularities can still be identified from the aggregated results for the entire period.

Table 6.3. TFP contributions to economic growth (%)

Country	The entire 2015–2024 period		The period before the COVID-19 pandemic (2015–2019)		The period after the COVID-19 pandemic (2021–2024)	
	TFP	TFP_{corr}	TFP	TFP_{corr}	TFP	TFP_{corr}
Bulgaria	65	53	58	44	70	55
Croatia	70	59	72	60	59	46
Czech Republic	–55	–272	47	23	–224	–743
Estonia	371	488	32	9	853	1,168
Lithuania	–311	–482	43	27	–162	–223
Latvia	74	72	36	16	113	131
Poland	**–19**	**–67**	**56**	**43**	**–155**	**–270**
Romania	40	30	64	58	–12	–31
Slovakia	2	–26	22	3	–51	–102
Slovenia	70	45	75	50	52	15
Hungary	63	49	43	27	70	50
Average*	**34**	**–5**	**50**	**33**	**56**	**9**

* Unweighted averages.

Source: own elaboration based on data from IMF, ILO, the World Bank, and Eurostat.

As shown by the data presented in Table 6.3, the percentage TFP contributions (calculated using a standard method) to economic growth ranged between 40–74% in many countries (with the exception of countries with extremely atypical values) during the period 2015–2024. This confirms the significant impact of TFP on the economic growth of the analysed countries over the last decade.[6] The average for the EU-11 group as a whole was 34%, which means that one third of the economic growth in this cluster over the last 10 years is attributable to technological progress. This constitutes an extremely important conclusion arising from the analysis.

However, with regard to corrected total TFP, it should be noted that its contribution was slightly lower and, in many countries, ranged from 30% to 72%. The average for the EU-11 cluster as a whole is negative, due to negative values recorded in several CEE countries, particularly Lithuania and the Czech Republic.

Broken down into individual sub-periods, the representative results for the contribution of TFP to economic growth refer to the pre-pandemic period, during

[6] The significant contribution of TFP to economic growth is not inconsistent with the possibility of achieving low TFP growth rates. Here, we are referring to TFP contributions expressed in relative (percentage) terms, which can take on high values when the rates of change are low. This occurs when GDP also shows low growth rates.

which all countries recorded a positive contribution of TFP to economic growth, calculated using both the standard and corrected methods. For the EU-11 cluster, the average values amounted to 50% and 33%, respectively. By contrast, the results for 2021–2024 should be interpreted with caution, as many countries achieved artificially low or artificially high figures during that period due to atypical macroeconomic performance, with growth accounting generating spurious results.

Finally, it is worth mentioning that other Polish researchers have also examined the decomposition of economic growth and TFP estimates for Poland (apart from our own previously cited research).[7] For example, Florczak and Welfe [2000] and Welfe [2001] calculate TFP in Poland over the period from 1982 to 2000 on the basis of standard growth accounting with two factors of production: labour and tangible capital (plant and machinery or total fixed assets). In their study, the elasticity of production with respect to fixed assets, i.e. the tangible capital income share, is either calibrated at 0.5 or estimated from the production function. In another study, Welfe [2003] estimates TFP for Poland between 1986 and 2000 using different alternative values for the tangible capital income share (from 0.25 to 0.7). Florczak [2011], on the other hand, calculates TFP values cleared of short-term demand fluctuations for Poland over the period 1970–2008 using the Wharton method, and subsequently examines the determinants of total factor productivity.

TFP estimates for Poland were also performed by, *inter alia*, Zienkowski [2001], Rapacki [2002], Piątkowski [2004] and Ptaszyńska [2006]. Roszkowska [2005] and Tokarski, Roszkowska and Gajewski [2005] performed growth accounting analyses for Polish voivodeships, while Bolińska [2018], Dykas and Misiak [2018] and Dańska-Borsiak [2020] conducted growth accounting analyses for selected Polish poviats. Zielińska-Głębocka [2004] estimated TFP for 100 industries in Poland, Ciołek and Umiński [2007] calculated TFP growth rates for Polish domestic and foreign enterprises, while Doebeli and Kolasa [2005] used the index number decomposition method in growth accounting analyses for Poland, the Czech Republic and Hungary. Finally, Ulrichs and Gosińska [2020] estimated the parameters of sectoral production functions describing the impact of variables representing tangible capital and labour on gross value added in Poland, while Młynarzewska-Borowiec [2018] estimated the level and dynamics of TFP in EU countries, including Poland, in the years 2000–2014.

It is also worth mentioning research in this area conducted for Poland by Statistics Poland [Kotlewski, Błażej, 2016, 2018, 2020]. The authors use the KLEMS productivity accounting framework and estimate, *inter alia*, the contribution of the economy's

[7] Due to volume constraints, this chapter does not describe the detailed results contained in these studies.

multifactor productivity (MFP) to production growth. The empirical analysis is conducted both at national level (for Poland and selected other EU Member States) and taking into account Polish voivodeships and individual sectors of the economy.

6.5. Conclusions

The results obtained indicate that productivity changes have played a significant role in the economic growth of Poland and the other EU-11 countries, despite the low growth rates of TFP. In Poland, the average TFP growth rate (calculated using the standard method) amounted to 1.7% per year over the period 2015–2024, which represented the fifth result among the EU-11 countries (with Croatia ranking first with a productivity growth rate of 2.2%). The EU-11 group as a whole recorded an average TFP growth rate of 1.2% between 2015 and 2024.

In the case of TFP calculated using the corrected method, i.e. excluding the impact of R&D sector activity on productivity growth, the estimates obtained are slightly lower. For Poland, the average growth rate of corrected TFP amounted to 0.9%, while for the EU-11 cluster as a whole it was 0.6%.

The increase in TFP in Poland should be interpreted as an improvement in the competitiveness of the Polish economy. Higher factor productivity implies greater economic efficiency and a stronger competitive position in the international environment.

The COVID-19 pandemic and the war in Ukraine had a negative impact on TFP growth. Between 2021 and 2024, most CEE countries, as well as the EU-11 cluster as a whole, recorded weaker performance in terms of TFP dynamics (calculated using both the standard and corrected methods) compared with the pre-pandemic period.

References

Abramovitz, M. (1956). Resource and Output Trends in the United States Since 1870, *American Economic Review*, 46(2), pp. 5–23.

Barton, G.T., Cooper, M.R. (1948). Relation of Agricultural Production to Inputs, *Review of Economics and Statistics*, 30(2), pp. 117–126.

Bolińska, M. (2018). Zróżnicowanie łącznej produktywności czynników produkcji w powiatach województwa podkarpackiego, *Humanities and Social Sciences*, 23(2), pp. 49–63. DOI: 10.7862/rz.2018.hss.20.

Caselli, F., Tenreyro, S. (2005). Is Poland the Next Spain? *NBER Working Paper*, 11045. DOI: 10.3386/w11045.

Ciołek, D., Umiński, S. (2007). Transfer technologii przez zagranicznych inwestorów, *Ekonomista*, 2, pp. 221–234.

Dańska-Borsiak, B. (2020). PKB i TFP w powiatach województwa wielkopolskiego. Oszacowanie i ocena zróżnicowania, *Rozwój Regionalny i Polityka Regionalna*, 52, pp. 11–28. DOI: 10.14746/rrpr.2020.52.02.

Doebeli, B., Kolasa, M. (2005). Rola zmian cen dóbr handlowych we wzroście dochodu krajowego Polski, Czech i Węgier, *Gospodarka Narodowa. The Polish Journal of Economics*, 202(9), pp. 25–45. DOI: 10.33119/GN/101512.

Dykas, P., Misiak, T. (2018). Przestrzenne zróżnicowanie łącznej produktywności czynników produkcji w grupach powiatów, *Studia Prawno-Ekonomiczne*, 109, pp. 205–224. DOI: 10.26485/SPE/2018/109/13.

Eurostat (2025). *Database*, https://ec.europa.eu/eurostat (accessed: 20.10.2025).

Florczak, W. (2011). Ekonometryczna analiza makro-uwarunkowań wzrostu gospodarczego Polski, *Prace i Materiały Wydziału Zarządzania Uniwersytetu Gdańskiego*, 4(8), pp. 75–92.

Florczak, W., Welfe, W. (2000). Wyznaczanie potencjalnego PKB i łącznej produktywności czynników produkcji, *Gospodarka Narodowa. The Polish Journal of Economics*, 164(11–12), pp. 40–55. DOI: 10.33119/GN/113989.

Griliches, Z. (1964). Research Expenditures, Education, and the Aggregate Agricultural Production Function, *American Economic Review*, 54(6), pp. 961–974.

Griliches, Z. (1996). The Discovery of the Residual: A Historical Note, *Journal of Economic Literature*, 34(3), pp. 1324–1330.

ILO (2025). *Ilostat Database*, https://ilostat.ilo.org/data (accessed: 20.10.2025).

IMF (2025). *World Economic Outlook Database. October 2025*, https://data.imf.org/en/datasets/IMF.RES:WEO (accessed: 16.10.2025).

Jasiński, A.H. (2021). Czy mamy stagnację innowacji w polskim przemyśle?, *Gospodarka Narodowa. The Polish Journal of Economics*, 305(1), pp. 111–134. DOI: 10.33119/GN/132484.

Johnson, D.G. (1950). The Nature of the Supply Function for Agricultural Products, *American Economic Review*, 40(4), pp. 539–564.

Jorgenson, D.W., Griliches, Z. (1967). The Explanation of Productivity Change, *Review of Economic Studies*, 34(3), pp. 249–283. DOI: 10.2307/2296675.

Kendrick, J.W. (1956). Productivity Trends: Capital and Labor, *Review of Economics and Statistics*, 38(3), pp. 248–257. DOI: 10.2307/1925777.

King, R.G., Levine, R. (1994). Capital Fundamentalism, Economic Development, and Economic Growth, *Carnegie-Rochester Conference Series on Public Policy*, 40, pp. 259–292. DOI: 10.1016/0167-2231(94)90011-6.

Kotlewski, D., Błażej, M. (2016). Metodologia rachunku produktywności KLEMS i jego implementacja w warunkach polskich, *Wiadomości Statystyczne*, 61(9), pp. 86–108. DOI: 10.5604/01.3001.0014.1098.

Kotlewski, D., Błażej, M. (2018). *Rachunek produktywności KLEMS – Polska 2005–2016*. Warszawa: Statistics Poland.

Kotlewski, D., Błażej, M. (2020). Sustainability of the Convergence Between Polish and EU Developed Economies in the Light of KLEMS Growth Accounting, *Bank i Kredyt*, 51(2), pp. 121–142.

Maszczyk, P., Próchniak, M., Rapacki, R. (2024). Development Trajectories in Central and Eastern European Countries in 2004–2023 – Sources of the Institutional Comparative Advantage and Their Evolution in Patchwork Capitalism. In: *Report of the SGH Warsaw School of Economics and the Economic Forum 2024* (pp. 15–52), A. Chłoń-Domińczak, R. Sobiecki, M. Strojny, B. Majewski (Eds.). Warsaw: SGH Publishing House.

Młynarzewska-Borowiec, I. (2018). Łączna produktywność czynników produkcji (TFP) i jej zróżnicowanie w krajach Unii Europejskiej, *Acta Universitatis Lodziensis. Folia Oeconomica*, 3(335), pp. 109–122. DOI: 10.18778/0208-6018.335.08.

Nonneman, W., Vanhoudt, P. (1996). A Further Augmentation of the Solow Model and the Empirics of Economic Growth for OECD Countries, *The Quarterly Journal of Economics*, 111(3), pp. 943–953. DOI: 10.2307/2946677.

Piątkowski, M. (2004). Wpływ technologii informacyjnych na wzrost gospodarczy i wydajność pracy w Polsce w latach 1995–2000, *Gospodarka Narodowa. The Polish Journal of Economics*, 189(1–2), pp. 37–52. DOI: 10.33119/GN/113750.

Próchniak, M. (2012). Total Factor Productivity. In: *Poland. Competitiveness Report 2012. Focus on Education* (pp. 189–203), M.A. Weresa (Ed.). Warsaw: SGH Publishing House.

Próchniak, M. (2014). Changes in Total Factor Productivity in 2004–2013 and the Competitiveness of the Polish Economy. In: *Poland. Competitiveness Report 2014. A Decade in the European Union* (pp. 192–204), M.A. Weresa (Ed.). Warsaw: SGH Publishing House.

Próchniak, M. (2020). Changes in Total Factor Productivity, with a Particular Focus on the Service Sector. In: *Poland. Competitiveness Report 2020. Focus on Service Sector* (pp. 183–204), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M. (2022). Changes in Total Factor Productivity. In: *Poland. Competitiveness Report 2022. Towards a Sustainable Economy in a Pandemic Era* (pp. 123–136), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Próchniak, M. (2023). Total Factor Productivity. In: *Poland. Competitiveness Report 2023. Focus on Entrepreneurship and Competitive Advantages* (pp. 93–107), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Warsaw School of Economics.

Próchniak, M. (2024). Total Factor Productivity. In: *Poland. Competitiveness Report 2024. The Role of Public Health in Creating Competitive Advantages* (pp. 91–105), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Warsaw School of Economics.

Próchniak, M. (2025). Changes of Total Factor Productivity. In: *Poland. Competitiveness Report 2025. Reconfiguring Global Value Chains and Shaping Competitive Advantages* (pp. 99–112), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

Ptaszyńska, B. (2006). Wzrost gospodarczy w Polsce w latach transformacji systemowej, *Wiadomości Statystyczne*, 51(2), pp. 44–53.

Rapacki, R. (2002). Możliwości przyspieszenia wzrostu gospodarczego w Polsce, *Ekonomista*, 4, pp. 469–493.

Rapacki, R. (Ed.). (2019). *Diversity of Patchwork Capitalism in Central and Eastern Europe*. London: Routledge.

Rapacki, R., Maszczyk, P., Lissowska, M., Próchniak, M., Sulejewicz, A. (2025). Patchwork Capitalism and Economic Development Trajectories of CEE11 Countries in 2004–2022, *Eastern European Economics*, 63(6), pp. 845–874. DOI: 10.1080/00128775.2025.2499043.

Rapacki, R. (Ed.), Próchniak, M., Czerniak, A., Gardawski, J., Horbaczewska, B., Karbowski, A., Maszczyk, P., Towalski, R. (2019). *Kapitalizm patchworkowy w Polsce i krajach Europy Środkowo-Wschodniej*. Warszawa: PWE.

Roszkowska, S. (2005). Kapitał ludzki a wzrost gospodarczy w ujęciu wojewódzkim, *Wiadomości Statystyczne*, 50(4), pp. 46–67.

Ruttan, V.W. (1956). The Contribution of Technological Progress to Farm Output: 1950–75, *Review of Economics and Statistics*, 38(1), pp. 61–69. DOI: 10.2307/1925559.

Schmookler, J. (1952). The Changing Efficiency of the American Economy, 1869–1938, *Review of Economics and Statistics*, 34(3), pp. 214–231. DOI: 10.2307/1925628.

Solow, R.M. (1957). Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39(3), pp. 312–320. DOI: 10.2307/1926047.

Solow, R.M. (1962). Technical Progress, Capital Formation, and Economic Growth, *American Economic Review*, 52(2), pp. 76–86.

Tintner, G. (1944). A Note on the Derivation of Production Functions from Farm Records, *Econometrica*, 12(1), pp. 26–34. DOI: 10.2307/1905565.

Tokarski, T., Roszkowska, S., Gajewski, P. (2005). Regionalne zróżnicowanie łącznej produktywności czynników produkcji w Polsce, *Ekonomista*, 2, pp. 215–244.

Ulrichs, M., Gosińska, E. (2020). Sektorowe funkcje produkcji – wnioski z modeli panelowych dla Polski, *Gospodarka Narodowa. The Polish Journal of Economics*, 302(2), pp. 71–94. DOI: 10.33119/GN/116617.

Wang, Y., Yao, Y. (2003). Sources of China's Economic Growth 1952–1999: Incorporating Human Capital Accumulation, *China Economic Review*, 14(1), pp. 32–52. DOI: 10.1016/S1043-951X(02)00084-6.

Welfe, W. (2001). Czynniki wzrostu potencjału gospodarczego Polski, *Ekonomista*, 2, pp. 177–200.

Welfe, W. (2003). Łączna produktywność czynników produkcji a postęp techniczny, *Studia Ekonomiczne*, 1–2, pp. 99–115.

World Bank (2025). *World Development Indicators Database*, https://databank.worldbank.org (accessed: 19.10.2025).

Zielińska-Głębocka, A. (2004). Analiza produkcyjności polskiego przemysłu. Aspekty metodyczne i empiryczne, *Ekonomista*, 3, pp. 335–358.

Zienkowski, L. (2001). Wydajność pracy i kapitału w Polsce, *Wiadomości Statystyczne*, 46(2), pp. 36–49.

Part II

The Role of Research and Development in Building Competitive Capacity

Chapter 7

Poland's R&D Labour Market and Innovation Environment

Anna Maria Dzienis

7.1. Introduction

Poland's accession to the European Union in 2004 catalysed significant growth in its research and development (R&D) workforce and innovation capacity. Over the ensuing two decades, R&D employment expanded markedly, and human capital indicators improved in parallel with strong macroeconomic performance. Yet in recent years, Poland's overall competitiveness has faltered [IMD, 2025]. Indices of government and business efficiency have deteriorated amid fiscal imbalances, adverse tax policy shifts, and weakening institutional quality [IMD, 2025]. At the firm level, stagnant productivity, skills shortages, and limited managerial capacity have further undermined competitive performance. These developments, used as a reference rather than a benchmark [Buitrago, Torralba Barreto, Reyes, 2023], underscore a paradox: substantial talent and effort have produced strong outputs despite suboptimal tangible and financial inputs. In other words, Poland's workforce has delivered notable results even as R&D investment remains modest and support structures are fragmented.

In this context, it is worth recalling Pedersen's [2008, 2010] concepts of institutional competitiveness and the competition state, discussed in greater detail in the theoretical introduction to the 2023 Competitiveness Report by Weresa [2023]. The first refers to a nation's ability to construct an institutional order and shape its political, social, and cultural institutions in ways that support socio-economic success relative to other countries. The second concerns the governance capacities of the state administration, which mobilise domestic resources and enable the national production base to achieve comparative advantages in an open economy [Weresa, 2023, pp. 14–15]. Furthermore, Weresa [2023] emphasises that an economy's competitiveness rests on two components: the real sphere (domestic and foreign resources, alongside broadly understood infrastructure) and the institutional sphere (regulations, norms, value systems, etc.) [p. 15]. The latter is particularly important to keep in mind in the context of this chapter.

This is especially true given that competing nations not only reform their legal, political, economic, and cultural institutional environments to create comparative advantages but also deliberately build institutional complementarities by coordinating policies, societal actors, and multiple levels of government into governance systems designed for continuous learning and experimentation [Pedersen, 2008].

This chapter aims to provide a comprehensive assessment of the evolution of Poland's R&D labour market and innovation environment between 2004 and 2023, with particular attention to changes in employment structures, the quality of human capital, the level and composition of R&D expenditures, and R&D outputs. It seeks to identify key trends, barriers, and institutional factors that shape Poland's ability to leverage its R&D human resources to drive innovation-related activities and develop competitive advantages. The key indicators used in the study encompass the number of R&D personnel, the distribution of researchers by sector, and the outcomes of science, technology, engineering, and mathematics (STEM) education. The evolution of R&D policy and funding (public and private) is reviewed alongside R&D outputs, such as patent activity, and innovation-related activities, such as technology transfer, and the growth of startups. Drawing on data from Eurostat, Statistics Poland, and other sources, the analysis evaluates Poland's strengths and weaknesses in leveraging human capital for innovation. The findings emphasise the need to reform Poland's politicised and fragmented institutional framework into a more cohesive, competition-oriented model capable of fully exploiting its human capital for innovation-driven growth.

7.2. Growth of R&D employment and personnel

Poland's R&D workforce has expanded considerably since EU accession. In 2003, only about 126,000 people were employed in R&D, whereas by 2023 this figure reached 326,100, more than a two-and-a-half-fold increase [NCBR, 2025]. However, the share of R&D personnel in Poland's total labour force remains modest at around 1%, below the EU average of 1.4% [Research in Poland, 2022]. This indicates that despite rapid growth, R&D workers still form a relatively small fraction of Poland's workforce compared to more research-intensive European economies.

As shown in Table 7.1, Poland's R&D intensity (expenditure as % of GDP) increased to 1.56% in 2023, up from around 0.54% in 2003 [NCBR, 2025]. Despite this long-term growth, it remains below the EU average of 2.3% [Eurostat, 2025a]. Moreover, in 2024, gross domestic expenditure on R&D *per capita* amounted to PLN 1,370, representing a 2.7% decrease compared with the previous year [Statistics Poland,

2025]. The composition of R&D personnel by sector in Poland differs slightly from that in the EU. As at 2023, over half of Polish researchers worked in business (56%), similarly to the EU average (57%), while a higher proportion (41%) worked in higher education, compared to the EU (32%). Interestingly, nowadays, Poland has an exceptionally low proportion of researchers in government institutes (only 3%, vs 10% EU-wide) [Eurostat, 2025d].

Table 7.1. Key R&D and human capital indicators – Poland vs EU (latest data)

	2013		2023	
Indicator:	Poland	EU Average	Poland	EU Average
R&D expenditure (% of GDP)	0.9%	2.1%	1.6%	2.3%
R&D personnel and researchers in the labour force (% of total employment, FTE)	0.6% (2014)	1.2% (2014)	1.2%	1.6%
Researchers in the business sector (% of all researchers)	28.8%	50.2%	56.4%	56.9%
Researchers in higher education (% of all researchers)	52%	35.5%	40.9%	31.5%
Researchers in the government sector (% of all researchers)	19%	13.6%	2.3%	10.2%
Tertiary graduates in STEM fields (% of all graduates; 2014 and 2023)	20.4%	25%	19.2%	25.2%
of which STEM F05	18.4%	23%	17%	25.3%
of which STEM F06	14.3%	12.2%	25.1%	18.6%
of which STEM F07	67.3%	64.8%	57.9%	57.9%

Note: 'Researchers' are a subset of R&D personnel who conduct research; STEM – science, technology, engineering, mathematics; ISCED-F05-natural sciences, mathematics and statistics, F06-information and telecommunication technologies, F07-engineering, manufacturing and construction.

Source: Author's own compilation based on Eurostat [2025a, 2025b, 2025d, 2025f].

According to Statistics Poland [2024], in 2023, 326.1 thousand people worked in R&D, up 1.5% from the previous year. Their actual involvement, measured in full-time equivalents (FTEs), reached 199.9 thousand, a 2.4% increase year-on-year. Internal staff dominated the R&D workforce (for indicators related to internal R&D personnel see Table 7.2), accounting for 81.7% of personnel by headcount and 83.7% by FTEs (compared with 81.8% and 84.1% in 2022). Moreover, entities employing 250 or more people accounted for the majority of R&D personnel, 72.4% by headcount and 71.6% by full-time equivalent (FTE). Across all size groups, internal staff dominated, especially in large entities (over 249 employees), where they represented 83.1% of total R&D staff by headcount and 84.4% by FTE. The highest share of external personnel was observed in micro-enterprises (up to 9 employees), accounting for 48.2% by headcount and 44.4% by FTE [Statistics Poland, 2024].

Table 7.2. Internal R&D personnel indicators

	2013	2016	2019	2022	**2024**
Number of entities in R&D	3122	4871	5863	7431	**7272**
Internal R&D personnel per 1000 *active population*[a]	5.4	6.5	8.1	9.5	**9.4**
of which researchers	4.1	5.1	5.9	6.9	**6.9**
Internal R&D personnel per 1000 *persons employed*[b]	6.0	6.9	8.4	9.8	**9.7**
of which researchers	4.6	5.4	6.1	7.1	**7.1**

Note: a) economically active population aged 15–89 according to the LFS – annual average data; b) employed persons aged 15–89 according to the LFS – annual average data. The first indicator relates R&D personnel to the entire labour force, offering a broader view of innovation potential. The second measures the intensity of R&D employment among those who are actually working.

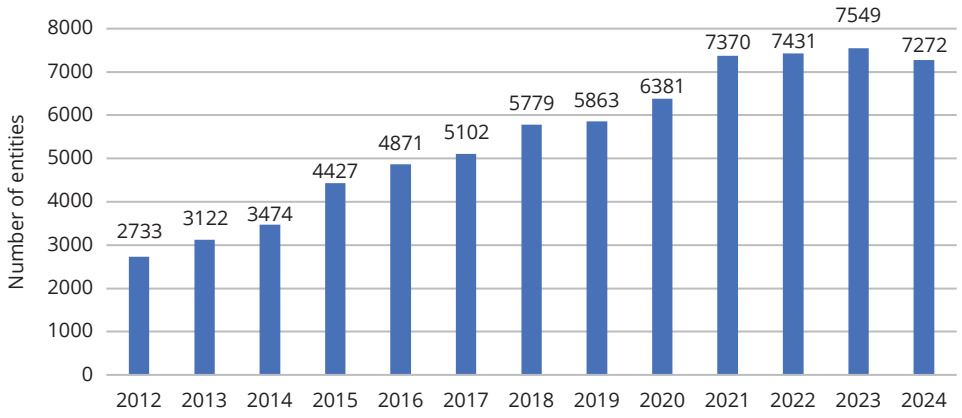
Source: Author's own compilation based on Statistics Poland [2025].

Researchers accounted for 69% of all R&D personnel, with women representing 36% of this group. Finally, according to Statistics Poland [2024], in 2023, labour costs accounted for 49% of total intramural R&D expenditure. The highest share of labour costs was recorded in entities with over 3,000 employees (53.6%), while the lowest was in those with up to 9 employees (26.5%). By field of research, the largest shares of R&D spending were in engineering and technology (48.3%), natural sciences (26.5%), and medical and health sciences (12.8%) [Statistics Poland, 2024].

7.3. Public versus private sector R&D employment

One of the most striking shifts since EU accession has been the rise of private-sector R&D employment in Poland. Greater business involvement in R&D has reshaped employment structures. In 2003, only 12% of R&D personnel were employed in the enterprise sector [NCBR, 2025], rising to 29% in 2013 and surpassing 50% by 2020 (Table 7.1). In other words, most R&D jobs are now in the business sector. The twelve-fold increase in R&D-active firms, from 548 in 2003 to nearly 7,000 in 2022, underscores how businesses have become central actors in Poland's research ecosystem [NCBR, 2025; Statistics Poland, 2024; Figure 7.1]. The business sector's share of national R&D expenditures (BERD) likewise rose from just 0.13% of GDP in 2013 to 1.01% in 2023 [NCBR, 2025]. This convergence toward the structure seen in advanced economies, where enterprises fund 66% of R&D on average [Eurostat, 2024], signals that research activity in Poland has moved "closer to the market" [NCBR, 2025]. However, as Jasiński [2025] notes, although rising R&D effort should, in theory, drive innovation, this relationship has not yet been observed [p. 81].

Figure 7.1. Number of R&D-active entities (2012–2024)



Source: Author's own compilation based on Statistics Poland [2025].

The public sector, while relatively less dominant than before, has also expanded R&D employment in absolute terms. Dedicated research entities, including universities and public research institutes, still employed 169,227 R&D personnel in 2023 (nearly 52% of total R&D personnel) [Statistics Poland, 2024]. Many of these are in higher education, which remains the single largest employer of researchers in Poland. However, the role of government research institutes is comparatively small, contributing only a few percent of researchers, a gap partly explained by historical underinvestment in standalone public R&D centres.

Another important aspect of human capital is the qualification level of R&D staff. In the early 2000s, Polish industry had very few PhD-qualified researchers. For example, in 2003, only 166 of those employed as R&D personnel in the entire business sector held a doctoral degree, constituting 2% [NCBR, 2025]. This number has since risen sharply. In 2023, 17.1% of R&D staff held a PhD, 7.7% were habilitated doctors (holders of the postdoctoral habilitation degree), and 4.6% held the title of professor [Statistics Poland, 2024; Table 7.3].

According to Statistics Poland [2024], in 2023, 81.6% of R&D personnel were employed in the services sector, while 17.3% worked in manufacturing. Among R&D staff in services, 20% held a PhD, 9% were habilitated doctors, and 6% held the title of professor. The education sector accounted for the largest share of total R&D employment (38.9%), including 33% PhD holders, 17% habilitated doctors, and 9% professors. Other key service sectors included ICT (18.9%) and professional, scientific, and technical activities (16.5%). In manufacturing, 3% of R&D personnel held a PhD, 1% were professors, and habilitated doctors represented less than 1%.

Table 7.3. R&D personnel by main group, educational level, and sector of performance in 2023

Sectors of performance:	Share in total R&D personnel (%) with educational level				
	Tertiary				Persons with other educational level
	with professor title	with a scientific degree		others	
		habilitated doctor	doctor (PhD)		
Total	4.6	7.7	17.1	57.9	12.7
Enterprise sector	0.6	0.6	4.3	76.7	17.7
Government sector	6.4	8.5	22.3	48.6	14.3
Higher education sector	9.5	16.4	32.4	35.2	6.5

Source: Author's own compilation based on Statistics Poland [2024].

By 2023, Polish businesses employed nearly 9,678 people with at least a doctoral degree in R&D roles [Statistics Poland, 2024]. While that remains a fraction (about 5.5%) of the 174,982 R&D personnel in business, it marks substantial progress in attracting highly educated talent into industry. The *internationalisation* (understood as the hiring of researchers from abroad) of the R&D workforce has also accelerated: in 2013, only 132 researchers from Asia worked in Polish R&D, but by 2022, over 2,300 Asian researchers were employed, alongside a jump in EU-foreign researchers from 596 to 6,753 in Poland [NCBR, 2025]. This indicates Poland is increasingly able to draw foreign scientific talent, enriching its human capital base for innovation.

7.4. Education and STEM talent pipeline

Poland's advances in R&D are underpinned by improvements in human capital and education. Between 2010 and 2020, Poland made significant progress in the World Bank's Human Capital Index, which measures the contributions of health and education to worker productivity. By 2020, Poland reached a score of 0.75 (on a scale from 0 to 1), placing it on par with Germany [World Bank, 2025]. In terms of education, the share of young adults with a university degree nearly doubled over the past two decades – by 2024, 45.7% of Poles aged 25–34 had tertiary education (22.6% in 2004, 43.5% in 2016), above the EU's 44.1% benchmark [Eurostat, 2025c]. In 2023, the highest female-to-male ratios among tertiary graduates in the EU were recorded in Latvia (197 women per 100 men), Poland (189 per 100), and Estonia (181 per 100) [Eurostat, 2025e]. This expansion of higher education has fed more graduates into the research and high-tech workforce. However, the mix of fields studied is a critical factor for R&D.

In particular, STEM (science, technology, engineering, mathematics) education is vital for supplying researchers and engineers. Here, Poland faces challenges. The absolute number of STEM graduates has decreased, as has their proportion among all graduates. In 2023, only 19.2% of Poland's tertiary graduates were in STEM fields. This is significantly below the EU average of roughly 25.2%. Compared to 2014, the number of STEM graduates decreased by 48%, from 113,835 to 76,992 (while the total number of graduates fell by 39%). While the share of ICT graduates increased by 19.1% between 2014 and 2023, the share of engineering, manufacturing, and construction graduates fell by nearly 42%, and graduates in natural sciences, mathematics, and statistics declined by 39% [Eurostat, 2025b]. These figures suggest Poland produces comparatively fewer engineers per cohort than many European peers, which presents a potential bottleneck for R&D labour supply.

In 2023, bachelor's and master's students accounted for 88.7% of all tertiary students in the EU, with the highest share in Poland (98.2%). Poland also recorded the lowest share of doctoral students, at just 1.7% of all tertiary enrolments. In 2023, 59.5% of all tertiary students in Poland were female, close to the share in Sweden (60.5%), the EU leader [Eurostat, 2025e]. Women account for 48% of doctoral graduates in the EU and 53.4% in Poland. Gender balance is reached in the higher education and government sectors, where women make up 44% and 45% of researchers at the EU level, and 46.8% and 55.5% in Poland. In the business sector, however, women represent only 24% of researchers, highlighting a substantial gender gap in a critical area for the EU's competitiveness [European Commission, 2024].

According to the *Education and Training Monitor 2025* issued by the European Commission [2025], Poland has met EU targets for early childhood education (96.6% participation for children aged three to the start of compulsory schooling) and tertiary attainment but faces major skill and workforce challenges. Basic skills have declined since 2018, and tertiary STEM enrolment remains relatively low despite high salaries and low unemployment for STEM graduates. Teacher shortages are severe across schools and early childhood education and care (ECEC), where teachers earn only 71% of similarly educated workers. Participation in adult learning is very low at 20.3% (vs EU 39.5%), contributing to persistent skills gaps. Vocational education and training enrolment is high (58.9%), but recent graduates' employment has dropped to 75.4% (below the EU's 80%). For children under three, ECEC participation remains low at 15.1% (vs the 2030 target of 23.6%). Poland is implementing reforms, including new curricula, digital education strategies, ECEC expansion, and dropout-reduction measures, but effective monitoring will be crucial to address these structural challenges [European Commission, 2025].

7.5. R&D investment and recent policy developments

Since 2004, Poland's public policy and investment in R&D have evolved from a low base to a more mature, innovation-driven framework. Gross domestic expenditure on R&D (GERD) has risen markedly. In nominal terms, Poland spent only PLN 4.5 billion on R&D in 2003 [NCBR, 2025]; by 2023, this had surged to PLN 53.1 billion, nearly a 12-fold increase [Statistics Poland, 2024]. As a share of the economy, GERD grew from 0.54% of GDP in 2003 to 1.56% in 2023 [NCBR, 2025]. This threefold increase in R&D intensity reflects efforts to "catch up" to Western Europe. Indeed, Poland recorded one of the largest R&D intensity gains in the EU over the past decade (+0.7 percentage points between 2013 and 2023), compared with a modest increase of just 0.1 percentage points for the EU as a whole [Eurostat, 2024]. Projections suggest that, at the current trajectory, Poland could reach the EU's current average R&D intensity around 2030; however, the EU aims to achieve 3% R&D intensity by that time – the so-called Barcelona target, adopted in 2002, which set the goal of raising R&D expenditure across the EU to 3% of GDP – implying that Poland would need to accelerate efforts to achieve full convergence [NCBR, 2025]. Thus, Poland is still closing in on the EU but it is not closing the gap [Jasiński, 2025, p. 77].

Public R&D funding has undergone major reforms. Early in the EU membership period (2007–2010), Poland built an institutional framework to distribute the growing funds. The National Centre for Research and Development (Polish abbreviation: NCBR) was established in 2007 as a lead agency for applied R&D, and the National Science Centre (Polish abbreviation: NCN) in 2009 for basic research. These agencies were established as part of the reorganisation of the Committee for Scientific Research (Polish abbreviation: KBN). Between 2007 and 2024, NCBR signed over 13,000 R&D project contracts; more than half of NCBR's projects have been co-financed by EU structural funds, under programmes such as the Operational Programme Innovative Economy (2007–2013), Smart Growth (POIR, 2014–2020), and the ongoing European Funds for a Modern Economy (FENG, 2021–2027) [NCBR, 2025].

Policymakers also introduced R&D tax incentives and legal reforms to stimulate private R&D [for a detailed analysis, see Tużnik and Jasiński, 2022]. Starting in 2016, Poland rolled out generous R&D tax credits, increasing deduction rates for R&D labour and costs [European Commission, 2017]. Further enhancements in 2017 and 2018 ('Innovation Act') extended these credits and even allowed cash refunds for startups conducting R&D [European Commission, 2017; Ministry of Science and Higher Education, n.d.]. Additionally, the government's Responsible Development Plan (2016)

positioned R&D and innovation at the centre of economic modernisation, setting a target of increasing R&D spending to 2% of GDP by 2020 [Ministry of Investment and Development, 2019]. This goal, however, was not achieved.

7.6. Innovation-related activities: patents, technology transfer, and startups

The ultimate aim of investment in human capital for R&D is to drive innovation. Poland's performance in innovation-related activities is mixed, showing clear improvement in some areas (e.g., startup activity) but lingering gaps in others (e.g., patent output). Poland's domestic patent filings saw an initial uptick post-2004 but overall remain at modest levels. In the first decade of EU membership, the number of inventions and patents granted in Poland grew, peaking around 2011–2012 [NCBR, 2025]. Thereafter, patent activity stagnated or even declined.

According to the intellectual property statistical profile of Poland issued by WIPO [2025], Poland's patenting activity reflects a medium scale but steadily expanding innovation system characterised by strong domestic activity and relatively limited international reach. Total patent applications reached 5,931 in 2023, a 12.8% increase from the previous year, driven primarily by resident applicants, who accounted for 4,618 filings and 97.1% of the total. In contrast, abroad applications by Polish residents declined by 6.6% to 1,313, and the number of Patent Cooperation Treaty (PCT) international applications remained unchanged at 370, indicating stagnation in Poland's internationalisation of inventive activity. Patent grants decreased slightly to 2,261, while patents in force totalled 108,142. Poland ranked 28th globally and 14th in Europe in patent filings, and second in Eastern Europe with a 16.7% regional share. The technological profile of Polish patenting is highly diversified, with leading fields including medical technology (7.4%), civil engineering (7.1%), other special machines (5.8%), measurement (5.2%), and transport (5.2%). Among international destinations, the United States (35.6%) and the European Patent Office (33.9%) dominate, followed by China, Japan, and Canada, each with a share of less than 5%. Universities accounted for 15.2% of applications between 2021 and 2023, and women constituted 24% of listed inventors.

Moreover, most Polish patents (57%) are owned by research institutions (universities or institutes) rather than companies (36%) [NCBR, 2025], indicating that Polish businesses are less active in patenting the results of their R&D activities. One cited reason is a lack of confidence in IP enforcement – many firms doubt they can defend patents in court, so they hesitate to patent innovations [NCBR, 2025]. This points

to an area where policy and legal reforms could improve technology transfer from science to industry.

In terms of the startup ecosystem, in the early 2000s, Poland's startup scene was still embryonic. However, by the mid-2020s, Poland had blossomed into a regional startup hub: as shown by the Central and Eastern European startups 2025 report, the value of the entire startup ecosystem in the CEE region at the end of the first quarter of 2025 amounted to a record EUR 243 billion, with the largest share going to Poland [dealroom.co, 2025]. Of the more than 275 companies classified as scaleups in the CEE region, i.e., startups that have already reached the phase of rapid growth and obtained funding exceeding EUR 15 million, most operate in Poland. Polish companies are increasingly appearing in the lists of companies with the greatest potential to achieve unicorn status, startups which have a value of at least a billion dollars. In the entire CEE region, as many as 80% of unicorns were created with the participation of venture capital or private equity funds, but many Polish companies are developing without having to relocate their entire operations abroad, which proves the growing maturity of the domestic ecosystem.

Table 7.4. Innovation-related activities: patents, technology transfer, and startups

Area	Key indicators (latest available)	Main insights
Patent activity	▪ 5,931 patent applications (2023), +12.8% YoY ▪ 4,618 domestic filings (97% of total) ▪ 1,313 abroad filings (–6.6% YoY) ▪ 370 PCT filings (stagnation) ▪ 2,261 patents granted; 108,142 patents in force	Moderate domestic activity; weak internationalisation; slowdown in inventive output despite earlier growth
Patent ownership & technology transfer	▪ 57% of patents held by universities/institutes ▪ 36% held by firms ▪ Top fields: medical technology, civil engineering, special machines, measurement, transport	Limited business patenting and weak IP commercialisation; low confidence in IP enforcement hampers firms' patenting
Startup ecosystem	▪ CEE ecosystem value: EUR 243 billion (2025); Poland with the largest share ▪ 275+ CEE scaleups – most operating in Poland ▪ VC funding: EUR 2.3 billion (2024), +30% YoY; EUR 442 million in Q1 2025	Poland emerging as a regional startup hub; strong VC growth; technology teams remain in Poland despite HQ relocations; increasing maturity

Source: Author's own compilation based on dealroom.co [2025], NCBR [2025], WIPO [2025].

In 2024, Polish startups raised a total of EUR 2.3 billion in VC funding, which means an increase of about 30% compared to the previous year. In the first quarter of 2025, Polish technology companies have already raised EUR 442 million, which is 78% of the investment value from the same period of 2024. 48% of scaleups from the CEE region have moved their headquarters to another country, most often to the

United States or the United Kingdom [dealroom.co, 2025]. However, in most cases, also among Polish companies, the main technology and operational teams remain in the country of origin. This means that Polish R&D, engineering, and product centres have not only survived the globalisation of startups but have often gained new competencies as a result [dealroom.co, 2025].

Government support has played a certain role in this startup boom [for a detailed analysis, see Tużnik and Jasiński, 2022]. Moreover, the NCBR has run BRIdge Alfa seed funds and accelerators, as well as programmes such as Start in Poland and the Polish Agency for Enterprise Development (PARP)'s ScaleUp, which facilitated corporate-startup cooperation. Tax incentives and simplified procedures for new firms have improved conditions for entrepreneurs [Tużnik, Jasiński, 2022, pp. 151–153]. The result is a much more vibrant innovation-driven entrepreneurship landscape than Poland had in 2004. Challenges persist, such as scaling companies to global markets and boosting private R&D investment in higher-risk deep-tech[1] areas [Poland Insight, 2025]. Yet, the overall trend suggests gradual improvement: Poland's innovation ecosystem appears to be moving from a model largely reliant on imported technology toward one that is increasingly capable of developing and commercialising its own innovations.

7.7. Conclusions

Over two decades of EU membership, Poland has transformed its R&D labour market and expanded its innovation capacity, albeit unevenly and with persistent structural challenges. The country has significantly increased the scale of its R&D workforce: the number of R&D personnel more than doubled between 2003 and 2023, with the business sector emerging as the dominant employer of researchers. This development reflects a reorientation toward a more market-driven model of innovation, supported by rising private investment in R&D and increasingly sophisticated human capital. At the same time, the qualification profile of the R&D workforce has improved, with firms employing substantially more PhD-level researchers than in the early 2000s, and with growing internationalisation enhancing the diversity and competencies of Poland's research community.

Despite this progress, Poland's innovation environment continues to exhibit important weaknesses. The share of R&D personnel in total employment remains below the EU average, and STEM education outcomes reveal a declining number of

[1] 'An area of business or research that involves using advanced science and technology, such as artificial intelligence, blockchain, or advances in biotechnology, to provide solutions to complicated problems' [Cambridge Dictionary, n.d.].

graduates in critical fields, creating potential bottlenecks for future growth. Combined with a relatively small proportion of doctoral students, weak science-industry linkages, fragmented institutions, and historically low R&D intensity, these factors pose risks to building and sustaining a robust innovation pipeline.

Furthermore, innovation-related activities themselves present a mixed picture. Patent activity shows modest domestic gains but limited internationalisation and weak engagement by firms, which continue to hold a minority share of patents. Concerns about intellectual property enforcement and limited absorptive capacity hinder stronger science-industry linkages and delay the translation of research into commercial innovation. By contrast, a vibrant startup ecosystem has emerged, with rising venture capital investment and high-tech scale-ups signalling a nascent innovation culture in Poland's economy.

Fully capitalising on the country's human capital gains will require sustained efforts. Poland must continue investing in STEM education while strengthening support for technology transfer, intellectual property protection, and a pro-innovation business climate in a coordinated and systemic manner. The progress to date is substantial; Poland is far more innovative and research-active now than in 2004, but sustained commitment is needed for the country to move from simply catching up to truly becoming a leading knowledge-driven economy.

References

Buitrago, R.R.E., Torralba Barreto, D.R., Reyes, G.E. (2023). Are Competitiveness Rankings and Institutional Measures Helping Emerging Economies to Improve?, *Competitiveness Review*, 33(5), pp. 861–888. DOI: 10.1108/CR-04-2021-0064.

Cambridge Dictionary (n.d.). *Deep* Tech, https://dictionary.cambridge.org/dictionary/english/deep-tech (accessed: 26.01.2026).

dealroom.co. (2025). *Central and Eastern European Startups 2025*, https://share.google/qEkGx38nINkm0kdIh (accessed: 17.11.2025).

European Commission (2017). *Background Report. Peer Review of the Polish Research and Innovation System. Horizon 2020 Policy Support Facility*. Luxembourg: Publications Office of the European Union. DOI: 10.2777/920450.

European Commission (2024). *SheFigures*, https://projects.research-and-innovation.ec.europa.eu/en/knowledge-publications-tools-and-data/interactive-reports/she-figures-2024 (accessed: 17.11.2025).

European Commission (2025). *Education and Training Monitor 2025 – Poland*, https://op.europa.eu/en/publication-detail/-/publication/bf102136-bf8b-11f0-a612-01aa75ed71a1/language-en (accessed: 17.11.2025).

Eurostat (2024). *EU Spent €381.4 Billion on R&D in 2023*, https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20241211-2#:~:text=Business%20sector%3A%2066, R%26D%20spendings (accessed: 17.11.2025).

Eurostat (2025a). *GERD by Sector of Performance*, https://ec.europa.eu/eurostat/databrowser/view/rd_e_gerdtot/default/table?lang=en (accessed: 17.11.2025).

Eurostat (2025b). *Graduates by Education Level, Programme Orientation, Sex and Field of Education*, https://ec.europa.eu/eurostat/databrowser/view/educ_uoe_grad02__custom_18728558/default/table (accessed: 17.11.2025).

Eurostat (2025c). *Population in Private Households by Educational Attainment Level (%)*, https://ec.europa.eu/eurostat/databrowser/view/edat_lfs_9903__custom_18768741/default/table (accessed: 17.11.2025).

Eurostat (2025d). *Share of R&D Personnel and Researchers in Total Active Population and Employment by Sector of Performance and Sex*, https://ec.europa.eu/eurostat/databrowser/view/rd_p_perslf/default/table?lang=en (accessed: 17.11.2025).

Eurostat (2025e). *Tertiary Education Statistics*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tertiary_education_statistics (accessed: 17.11.2025).

Eurostat (2025f). *Total Researchers by Sector of Performance – Full-Time Equivalent*, https://ec.europa.eu/eurostat/databrowser/view/tsc00004/default/table (accessed: 17.11.2025).

IMD (2025). *World Competitiveness Ranking*, https://worldcompetitiveness.imd.org (accessed: 03.11.2025).

Jasiński, A. (2025). Innowacyjność przedsiębiorstw przemysłowych w latach 2015–2022. Mierniki i ocena w Polsce, *Gospodarka Narodowa. The Polish Journal of Economics*, 1(321), pp. 68–83. DOI: 10.33119/GN/194055.

Ministry of Investment and Development (2019). *Plan na rzecz Odpowiedzialnego Rozwoju*, https://www.gov.pl/web/archiwum-inwestycje-rozwoj/plan-na-rzecz-odpowiedzialnego-rozwoju (accessed: 03.11.2025).

Ministry of Science and Higher Eduction (n.d.). *Korzystne prawo*, https://www.gov.pl/web/nauka/korzystne-prawo (accessed: 03.11.2025).

NCBR (2025). *Jak zmieniło się B+R w Polsce po wejściu do Unii Europejskiej*, https://www.gov.pl/web/ncbr/jak-zmienilo-sie-br-w-polsce-po-wejsciu-do-unii-europejskiej#:~:text=, wzros%C5%82a%20o%20blisko%20jedn%C4%85%20pi%C4%85t%C4%85 (accessed: 03.11.2025).

Pedersen, O.K. (2008). *Institutional Competitiveness. How Nations Came to Compete.* Frederiksberg: Department of Business and Politics, Copenhagen Business School.

Pedersen, O.K. (2010). Institutional Competitiveness: How Nations Came to Compete. In: *The Oxford Handbook of Comparative Institutional Analysis* (pp. 625–658), G. Morgan, J.L. Campbell, C. Crouch, O.K. Pedersen, R. Whitley (Eds.). Oxford: Oxford University Press.

Poland Insight (2025). *Polish Companies Are Adopting Advanced Technologies – But Still Hesitate to Invest in Automation and Deep Tech*, https://polandinsight.com/polish-companies-are-adopting-advanced-technologies-but-still-hesitate-to-invest-in-automation-and-deep-tech-74328/#google_vignette (accessed: 03.11.2025).

Research in Poland (2022). *Eurostat Reveals New Statistics – Since 2010, the Number of Research Projects in Poland Has Almost Doubled*, https://researchinpoland.org/news/eurostat-reveals-new-statistics-since-2010-the-number-of-research-projects-in-poland-has-almost-doubled/ (accessed: 03.11.2025).

Statistics Poland (2024). *Research and Experimental Development in Poland in 2023*, https://stat.gov.pl/en/topics/science-and-technology/science-and-technology/research-and-development-in-poland-in-2023,7,13.html (accessed: 03.11.2025).

Statistics Poland (2025). *Research and Experimental Development in Poland in 2024*, https://stat.gov.pl/en/topics/science-and-technology/science-and-technology/research-and-experimental-development-in-poland-in-2024,7,14.html (accessed: 26.11.2025).

Tużnik, F., Jasiński, A.H. (2022). Government Incentives to Stimulate Innovation and Entrepreneurship in Poland. In: *Government Incentives for Innovation and Entrepreneurship. An International Experience* (pp. 125–158), M.M. Abdellatif, B. Tran-Nam, M. Ranga, S. Hodžić (Eds.). Cham: Springer Nature Switzerland AG.

WIPO (2025). *Intellectual Property Statistical Country Profile. Poland*, https://share.google/PsF74aclLxhPjOIsr (accessed: 17.11.2025).

Weresa, M.A. (2023). Definition and Factors of Competitiveness: A Review of the Scientific Literature. In: *Poland: Competitiveness Report 2023. Focus on Entrepreneurship and Competitive Advantages* (pp. 13–28), A.M. Kowalski, M.A. Weresa (Eds.). Warsaw: SGH Publishing House.

World Bank (2025). *Human Capital Index (Scale 0–1)*, https://data360.worldbank.org/en/indicator/WB_HCI_HCI?recentYear=false&year=2020 (accessed: 17.11.2025).

Chapter 8

Research and Development and Innovation in the Polish Economy

Arkadiusz Michał Kowalski, Małgorzata Stefania Lewandowska, Marzenna Anna Weresa

8.1. Introduction

Research and development (R&D) is one of the most important drivers of innovation, providing knowledge, technologies and new concepts that can be transformed into marketable solutions. Across these approaches, R&D is viewed as a key source of innovation.

The aim of this chapter is to identify the main trends in the development of R&D in Poland in comparison with the European Union and to determine the innovation position of the Polish economy in 2025. The starting point for the empirical analysis is a brief overview of theoretical approaches showing how perceptions of the role of research and development have evolved across successive generations of innovation models. Subsequently, the chapter examines R&D expenditure in Poland and research workforce resources, both from a national and regional perspective, as well as the changes in these factors over the last decade.

These considerations are further developed through an analysis of data from the Community Innovation Survey (CIS) for the years 2020–2022, which covers declarations by enterprises from EU countries, including Poland, on the implementation of product innovations, the operation of R&D departments, expenditure on R&D, and other costs associated with the introduction of innovations. This perspective allows an assessment of the position of Polish enterprises relative to enterprises from other EU countries with regard to the concepts under examination.

The chapter concludes with a summary that includes a brief analysis of changes in Poland's position in innovation rankings.

8.2. Research and development as a source of innovation: Insights from innovation models

An analysis of the sources of innovation, both at the level of individual enterprises and at the level of the economy as a whole, enables us to identify various approaches to innovation activity. One of the classic approaches is the linear model of innovation.

The linear supply-side model (often referred to as the technology push model) originates from the concept of innovation proposed by Joseph Schumpeter and is widely discussed in the literature on the subject [see, *inter alia*, Rothwell, 1994; Smith, 2010]. In this approach, R&D is essential for the creation of innovation, as the results of research conducted in scientific and academic institutions constitute the primary source of new solutions. Here, R&D serves as the primary driver of development by providing companies with external technological inspiration that can be transformed into innovations.

The subsequent stages of the innovation process involve transforming the results of basic research into applied research, followed by development and design work, and only then the implementation phase: production, marketing, and sales. R&D is therefore the starting point and the foundation of the entire innovation creation chain.

The role of scientific research is viewed somewhat differently in the demand-pull model of innovation, in which market demand plays a key role in the creation of innovation. This approach draws on the ideas of Jacob Schmookler [1965], who argued that new solutions emerge in response to changing consumer preferences and incomes, with demand acting as a stimulus for the creation of new products, services, or operating methods. Authors developing Schmookler's idea emphasise the two-way relationship between demand and innovation: demand inspires the creation of new products, while the innovations introduced can generate further growth in demand, thereby creating a kind of multiplier effect [Kleinknecht, Verspagen, 1990]. However, demand remains the main impulse of innovation activity, whereas research and development is treated as supporting rather than a leading factor in the innovation process. Furthermore, this approach emphasises the interrelationships between the phases of the innovation process [Fischer, 1999].

In subsequent research on innovation processes, increasing emphasis was placed on feedback loops combining the supply-side and demand-side perspectives. This approach gave rise to the interactive model, which later evolved into the so-called Kline and Rosenberg chain-linked innovation model [1986]. In this case, the role of science and research is associated with their continuous interaction with the innovation process. Rather than acting as a one-off impulse, science and research

influence all stages of the central innovation pathway. The results of both basic and applied research provide concepts, methods and technological guidance supporting design, prototype development, and subsequent implementation activities. As a result, science and the outcomes of R&D serve as a continuous source of information and adjustments, enabling solutions to be refined as work progresses. R&D can shape the direction of the innovation process at many different stages, increasing its effectiveness and paving the way for the creation of more advanced and competitive technologies. Furthermore, groundbreaking scientific discoveries play a key role in the emergence of radical innovations, as they can initiate the development of entirely new sectors of the economy or lead to a profound transformation of existing industries, thereby opening up completely new paths of technological development.

The next generation of innovation models – the network model – places greater emphasis on the accumulation and diffusion of knowledge and technology through interactions among actors than on the process of their creation. In addition to the accumulation of knowledge, the speed with which innovations are brought to market, as well as flexibility and adaptability, are also important for innovation activities. In the network model, learning processes play a key role. Innovation results from the pooling of knowledge resources held by different actors. Interactions between them contribute to the formation of dynamic innovation networks, which in turn fosters the development of knowledge and resources. These interactions encompass both the internal circulation of knowledge – derived from experience gained through operational activities, design, development work or even failures – and learning from external entities, such as suppliers, competitors, partners or users [Cowan, Jonard, Zimmermann, 2004].

The open innovation model, proposed by Henry Chesbrough [2003, 2017], is based on the premise that the effectiveness of innovation activities stems from the skilful acquisition, combination and utilisation of both internal and external knowledge. According to this approach, a company can use its own resources and conduct its own R&D work while outsourcing the commercialisation process, for example by selling licences to external parties. Conversely, it may acquire knowledge from its environment, develop it internally, and bring innovations to market independently or in collaboration with partners. In practice, there are numerous combinations of these approaches, and the choice of specific solutions depends on the company's resources, market characteristics, and the prevailing operating environment.

A systemic approach to innovation research encompasses various levels of analysis, ranging from the national level, where we deal with national innovation systems, to regional, metropolitan, sectoral or technological innovation ecosystems. The concept of innovation systems is the result of combining two main theoretical strands: the

evolutionary approach to understanding technological change [Nelson, Rosenberg, 1993] and the approach emphasising interactive learning processes [Freeman, 1987; Lundvall, 1992; Edquist, 1997]. According to this approach, R&D and the resulting knowledge, together with institutions (including innovation policy) and the interactions among the actors and institutions involved in the innovation process, determine the capacity of innovation systems to generate new solutions.

In summary, the role of R&D is perceived differently in various models of innovation processes, although it always remains significant. In the linear model, research results initiate the entire sequence of events leading to implementation. In the chain model, R&D influences all stages of the innovation process and supports iterative transitions between scientific discoveries and market needs, forming part of a complex network of feedback loops between the various actors involved in the process. In the network model of innovation activity, collaboration with external partners to create and develop new ideas and products is key in the creation of knowledge. This approach forms the basis of the open innovation model, according to which new solutions are created through the skilful integration of knowledge from internal company sources (its own R&D activities) and external research results. The systemic model of innovation, in turn, assumes that R&D constitutes one of the key elements of a national or regional innovation ecosystem, in which innovations emerge through the interaction of science with business, institutions, and public policy.

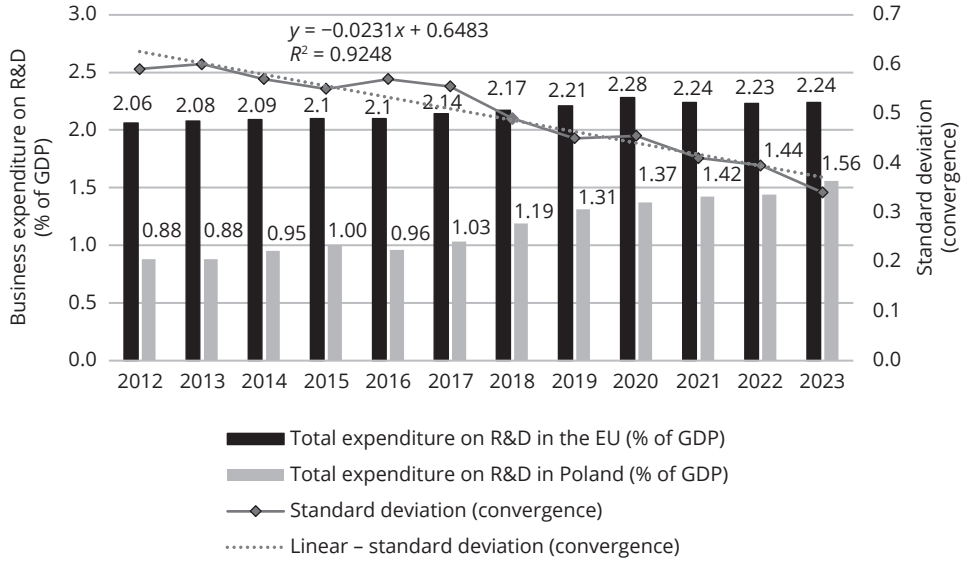
8.3. Research and development expenditure in Poland

One of the key measures of a company's innovation potential is its expenditure on R&D, expressed by the GERD (gross domestic expenditure on R&D) indicator. A high level of R&D expenditure reflects the innovation intensity of an economy: the greater the share of R&D expenditure in GDP, the greater the capacity to build knowledge-based competitive advantages and foster innovation-friendly ecosystems. In EU countries, especially among the innovation leaders, the GERD level often exceeds 3% of GDP, which translates into faster technological progress and a stronger competitive position in global markets. Figure 8.1 presents the ratio of R&D expenditure to GDP in Poland compared with the EU average over the period 2012–2023.

Between 2012 and 2023, the intensity of R&D expenditure in Poland increased systematically and at a faster pace than the EU average. At the beginning of this period, Poland spent 0.88% of GDP on R&D (compared with 2.06% of GDP in the EU in 2012); by 2023, however, this figure had risen to 1.56% of GDP, while the EU average

amounted to 2.24%. As a result, the gap relative to the EU narrowed, although it remained significant. This process indicates convergence, which is also confirmed by the decrease in the standard deviation (a measure of σ-convergence) between Poland and the EU from 0.59 to 0.34 between 2012 and 2023, reflecting a narrowing gap in the intensity of R&D expenditure between Member States (Figure 8.1). In other words, although Poland remains below the EU average, it is approaching the level observed in more advanced economies.

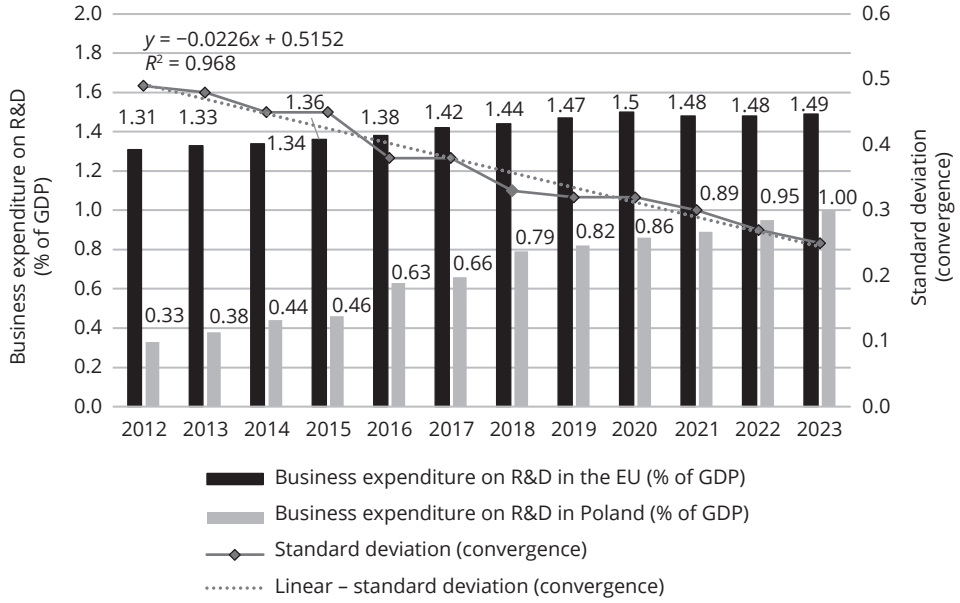
Figure 8.1. R&D expenditure as a percentage of GDP (GERD indicator) in Poland compared with the EU average between 2012 and 2023



Source: own elaboration based on Eurostat data.

In countries that are innovation leaders, the main source of funding for R&D is business expenditure. It is the private sector that drives the development and maintenance of technological advantage, while public funding plays a complementary role by strengthening framework conditions (the institutional environment), research infrastructure, and instruments supporting collaboration between science and business. This structure of expenditure shows that high innovation intensity is associated with the active involvement of businesses in financing R&D, which constitutes one of the key indicators of the maturity of an innovation system. A comparison of business expenditure on R&D as a percentage of GDP in Poland and the EU is presented in Figure 8.2.

Figure 8.2. Business R&D expenditure as a percentage of GDP in Poland compared with the EU average between 2012 and 2023



Source: own elaboration based on Eurostat data.

Between 2012 and 2023, business expenditure on R&D (BERD) in Poland also increased significantly. In 2012, it accounted for 0.33% of GDP (compared with 1.29% of GDP in the EU), while by 2023 it had risen to 0.96% of GDP, with the EU average amounting to 1.48% of GDP. This indicates that, despite the continuing gap relative to the EU, the growth rate in Poland was relatively high and the disparity narrowed to some extent. In terms of convergence, similarly to GERD, the standard deviation between Poland and the EU average decreased over the period under review, indicating that Poland is gradually aligning with the overall trend of an increasing share of business funding for innovation. At the same time, a significant gap remains relative to the most innovative economies in the EU, where the share of business funding for R&D reaches 2–3% of GDP. In Poland, the private sector is only gradually beginning to assume the role of the main provider of funding for innovation activity; for years, public support, including EU funds, played the dominant role. As a result, the development of innovation continues to rely to a large extent on external support mechanisms, although the activity of enterprises, especially SMEs, is steadily increasing.

8.4. Human resources in the research and development sector in Poland

R&D requires not only adequate funding but also highly qualified personnel. Both theoretical models and empirical research indicate that human capital is one of the key drivers of economic growth [see, *inter alia*, Romer, 1990; Mankiw, Romer, Weil, 1992; Fischer, 1999]. In the European Union, the human resources in science and technology (HRST) indicator is used to monitor progress in creating conditions conducive to innovation [Eurostat, 2025]. Changes in the HRST indicator can lead to structural transformations in innovation systems, thereby affecting job creation, resource and energy efficiency, and the pace of economic growth. This indicator measures the proportion of people aged 25–64 who meet at least one of two conditions: they possess tertiary education qualifications or, despite the absence of formal certification, work in science and technology professions where such qualifications are required. Consequently, it describes the segment of the economically active population that constitutes a highly skilled workforce.

Table 8.1. Evolution of human resources for science and technology in Poland compared with the EU in the years 2012–2024 (%)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
People with tertiary education (ISCED) as a percentage of the labour force													
Poland	29.6	31.0	32.4	33.3	34.3	35.4	36.5	38.2	38.8	38.8	39.2	42.8	44.4
EU-27	30.0	30.9	31.5	32.3	32.9	33.6	34.5	35.5	36.7	37.7	38.1	38.9	39.9
Employment in science and technology as a percentage of the population aged 25–64													
Poland	20.3	20.8	21.8	22.8	23.3	24.4	25.4	26.3	26.9	28.1	28.6	30.3	30.6
EU-27	24.2	24.4	24.8	25.3	26.0	26.6	27.2	27.9	28.1	29.0	29.6	30.3	31.1
Scientists and engineers as a percentage of the population aged 25–64													
Poland	4.8	4.9	5.1	5.2	5.3	5.6	5.9	6.2	6.3	6.7	6.9	7.7	8.1
EU-27	5.0	5.1	5.1	5.2	5.4	5.6	5.8	6.1	6.3	6.8	7.0	7.3	7.7

Source: own elaboration based on Eurostat data.

The data presented in Table 8.1 on the development of human resources for science and technology over the period 2012–2024 show a clear and systematic increase in the level of education and employment in science and technology in Poland during this period. The percentage of people with tertiary education in the labour force increased from 29.6% in 2012 to 44.4% in 2024, representing a faster growth rate than the EU-27 average (from 30% to 39.9%). Poland has therefore significantly narrowed the gap

with EU countries, reflecting the development of human capital and an increasingly strong focus on a knowledge-based economy. A similarly favourable trend can be observed in the share of employment in science and technology. Between 2012 and 2024, this share increased from 20.3% to 30.6%, which also exceeds the average growth rate in the EU. However, in absolute terms, the percentage of people employed in the science and technology sector remains slightly lower than in the EU-27.

A more detailed indicator describing human resources in the R&D sector – the share of scientists and engineers in the total population aged 25–64 – also shows systematic improvement. Between 2012 and 2024, this share increased in Poland from 4.8% to 8.1%, indicating a gradual strengthening of human resource potential in areas that are key to innovation.

In summary, data on human resources in science and technology indicate that, over the last decade, Poland has caught up with the EU average and, in some areas – especially in terms of the level of education – has even surpassed it. With adequate R&D funding, this could form the basis for the further development of Poland's high-tech and innovation sectors.

8.5. Research and development potential and the innovation potential of regions in Poland

The regional dimension plays a key role in the analysis of innovation potential, as the processes of knowledge creation and diffusion are highly territorial. It is at the regional level that ecosystems are formed, bringing together enterprises, universities and business support institutions that, thanks to the effects of agglomeration, proximity and trust, generate comparative advantages [Kowalski, 2022]. Ciborowski [2012] identified two similar but disproportionate approaches to the innovation development of regions: the cluster approach and the approach based on regional innovation systems (RIS). Both approaches draw on the experiences of regions that have achieved success in innovation; however, simply replicating them ignores the specific local economic and institutional conditions. In the cluster approach, the key role is played by enterprises, technology implementation and technology transfer, whereas the RIS approach places emphasis on institutions that develop pro-innovation policies, support R&D activities, and create conditions conducive to business innovation.

The diversity in the structure of the economy, human resources, research infrastructure and the quality of governance translates into heterogeneity in the intensity of R&D and innovation performance across individual voivodeships.

Data on the geographical distribution of R&D expenditure in Poland are presented in Table 8.2. The table illustrates internal R&D expenditure across voivodeships broken down into three complementary dimensions: the absolute value of R&D expenditure (in PLN million), R&D expenditure *per capita*, and expenditure intensity measured as a percentage of the voivodeship's GDP. This summary enables the simultaneous assessment of the scale of R&D activity, its *per capita* density, and the maturity of the ecosystem (share in GDP), i.e. three different aspects of regional technological competitiveness.

Table 8.2. Internal expenditure on R&D by region in Poland in 2023

Voivodeship	Expenditure (PLN million)	Expenditure *per capita*	Percentage of GDP (current prices)
Poland	53,115.9	1,409.0	1.56
Mazowieckie	17,977.0	3,263.0	2.22
Małopolskie	7,519.2	2,193.0	2.75
Pomorskie	4,743.8	2,011.5	2.33
Dolnośląskie	4,703.8	1,631.5	1.67
Śląskie	4,039.6	932.3	1.00
Wielkopolskie	3,829.6	1,097.2	1.15
Łódzkie	2,027.8	855.5	0.99
Lubelskie	1,732.6	858.7	1.41
Podkarpackie	1,543.5	743.6	1.20
Kujawsko-Pomorskie	1,225.7	612.3	0.86
Zachodniopomorskie	925.0	565.3	0.77
Warmińsko-Mazurskie	808.9	593.7	0.97
Podlaskie	702.8	616.1	0.92
Opolskie	521.7	555.3	0.79
Świętokrzyskie	497.3	423.9	0.64
Lubuskie	317.7	325.0	0.45

Source: Statistics Poland [2025].

The results presented in Table 8.2 confirm the strong spatial polarisation of R&D expenditure in Poland. Metropolitan voivodeships with mature knowledge ecosystems are characterised by the highest level of expenditure and above-average intensity (relative to GDP): Mazowieckie (PLN 17.98 billion; 2.22% of GDP; PLN 3,263 *per capita*), Małopolskie (PLN 7.52 billion; 2.75% of GDP; PLN 2,193 *per capita*), Pomorskie (PLN 4.74 billion; 2.33% of GDP; PLN 2,012 *per capita*) and Dolnośląskie (PLN 4.70 billion; 1.67% of GDP; PLN 1,632 *per capita*). When these three dimensions – scale, *per capita*

density and intensity – are combined, it becomes apparent that R&D functions are concentrated in the largest academic and business centres, where large technology employers, dense research infrastructure and collaborative networks coexist. Against this background, the national average of PLN 53.12 billion, PLN 1,409 *per capita* and 1.56% of GDP serves as a benchmark that the leading regions substantially exceed in terms of both the intensity and the quality of the innovation environment. The "middle" group of regions includes voivodeships with robust but less concentrated R&D activity. The Śląskie and Wielkopolskie voivodeships record high absolute expenditure amounts (PLN 4.04 billion and PLN 3.83 billion, respectively) while maintaining moderate *per capita* values and expenditure intensity (around 1.00–1.15% of GDP), which indicates a broad industrial base and a dispersion of R&D projects combined with a lower share of functions with the highest added value. In turn, the Lubelskie and Podkarpackie voivodeships stand out for their relatively favourable expenditure intensity (1.41% and 1.20% of GDP, respectively) combined with moderate *per capita* expenditure, which may be linked to the presence of specialised niches (e.g. life sciences, aerospace) supported by universities and research institutes, but with a smaller income base. The intensity of R&D expenditure in the Łódzkie and Kujawsko-Pomorskie voivodeships remains at around 1% of GDP, indicating a stable, albeit average, innovation profile.

At the opposite end of the spectrum are regions with a low intensity and limited "density" of R&D expenditure: Lubuskie (0.45% of GDP; PLN 325 *per capita*), Świętokrzyskie (0.64%; PLN 424 *per capita*), Zachodniopomorskie (0.77%; PLN 565 *per capita*) and Opolskie (0.79%; PLN 555 *per capita*). Low values, both relative to GDP and *per capita*, indicate weaker absorption and commercialisation of knowledge, a lower presence of large technology investors, and underdeveloped testing and implementation infrastructure.

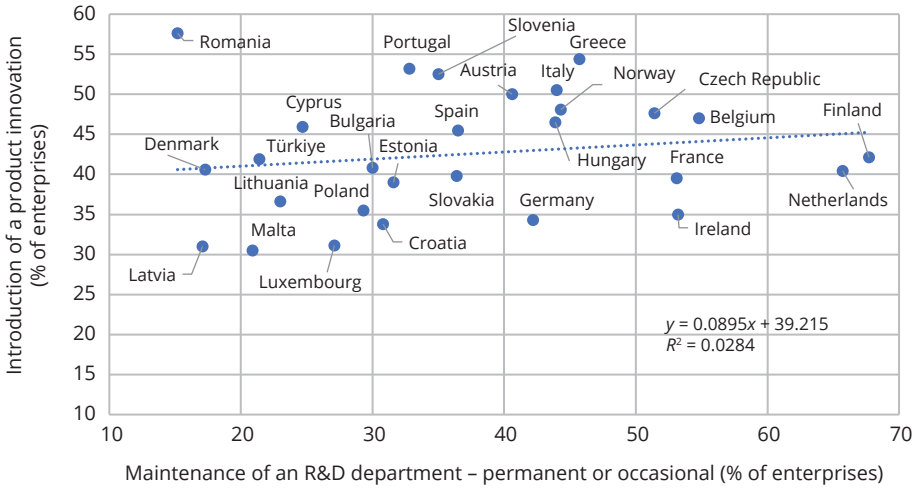
Overall, the picture that emerges from the regional analysis for 2023 is one of a concentration of R&D activity in a few "knowledge hubs" alongside a large group of voivodeships with catch-up potential. In this context, the implications for development policy are twofold: firstly, the advantages of the leading regions should be consolidated and strengthened (by focusing on the highest-value functions, such as R&D, design, software, and standards); and secondly, escalation pathways should be designed for peripheral regions (through the establishment of competence centres, test platforms, and supplier programmes) to enable them to narrow the gap relative to the metropolitan voivodeships in terms of R&D expenditure.

8.6. R&D activity and the innovativeness of Polish enterprises compared with EU entities in the light of the Community Innovation Survey (CIS) results for 2020–2022

This part of the study analyses the relationships between the structure of R&D activities undertaken by enterprises in EU countries, including Poland, and the level of their innovation performance. Particular attention is devoted here to the relationship between the existence of an R&D department, the intensity of research expenditures, and the frequency of introducing product innovation. This will enable us to assess the extent to which R&D infrastructure and expenditures translate into actual innovation outcomes.

Figure 8.3 illustrates the relationship between the X-axis (i.e. the percentage of enterprises with an R&D department operating either on a permanent or occasional basis) and the Y-axis (i.e. the percentage of enterprises introducing product innovation). Each point represents an EU country, while the dashed line indicates the linear trend described by the equation: $y = 0{,}0895x + 39{,}215$, $R^2 = 0{,}0284$.

Figure 8.3. Enterprises with an R&D department on a permanent or occasional basis vs the introduction of product innovations, 2020–2022



Source: own elaboration based on CIS 2022 data.

The slope coefficient of 0,0895 indicates that a 1 percentage point increase in the share of companies with an R&D department is associated, on average, with

a 0.09 percentage point increase in the share of companies introducing product innovation. The coefficient of determination $R^2 = 0{,}0284$ indicates a very weak relationship between these variables, as only around 2.8% of the variation in the introduction of product innovations can be explained by the presence of an R&D department.

The high share of businesses in Finland and the Netherlands with R&D departments does not directly translate into more frequent declarations of introducing product innovation than in other countries.

By contrast, entities from Romania and Portugal exhibit a relatively low share of companies investing in R&D departments while simultaneously reporting high levels of innovation introductions. With regard to entities from Lithuania, Malta and Luxembourg, in both cases they record values below the average for the group of countries surveyed.

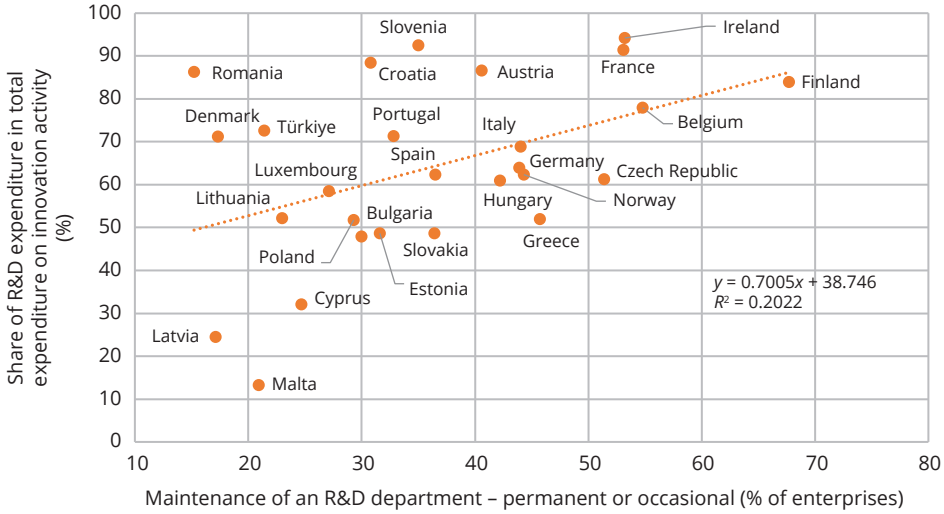
The weak correlation between the presence of an R&D department and the frequency of introducing product innovation does not imply that this expenditure is insignificant. Rather, it suggests that other factors (such as the institutional environment, science – business collaboration, and company size) have a much greater impact on the introduction of innovation than the mere existence of an R&D department.

The next step of the analysis examines whether there is a relationship between the R&D infrastructure maintained and the ratio of R&D expenditure to other expenditure related to innovation activity.

An analysis of the relationship between the percentage of enterprises maintaining R&D departments and the percentage share of R&D expenditure in total innovation expenditure over the period 2020–2022 indicates a positive relationship between these variables. Although countries with a higher proportion of companies reporting the existence of an R&D department tend to record a higher share of R&D expenditure, this correlation is not strong. The coefficient of determination R^2 is only approx. 0.20, indicating that only one-fifth of the variation in R&D expenditure across countries can be explained by the differences in the organisation level of R&D infrastructure within enterprises.

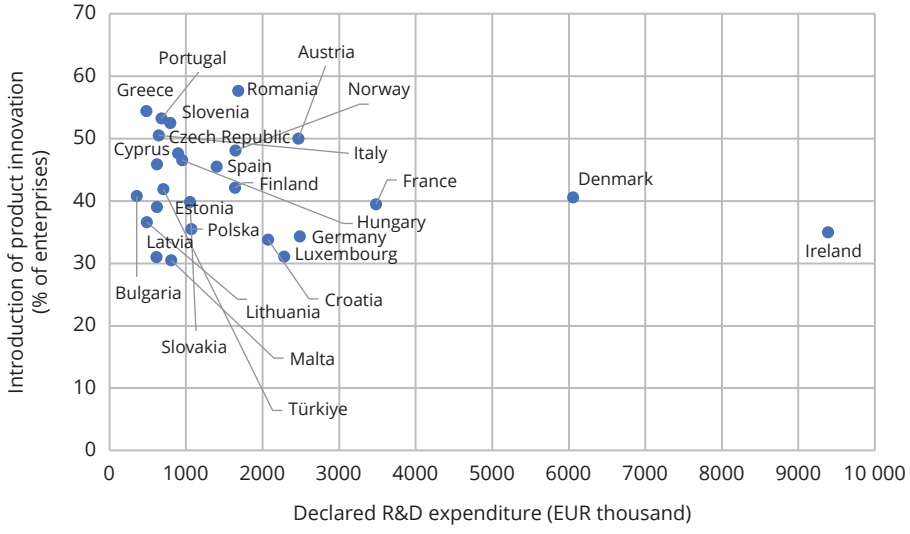
Figure 8.4 reveals significant differences between countries, with countries such as Croatia, Slovenia and Austria recording a significantly higher share of R&D expenditure, despite only a moderate proportion of enterprises with R&D departments. By contrast, Malta, Latvia and Cyprus lie clearly below the regression line, indicating a relatively low expenditure intensity despite the reported presence of R&D structures in enterprises, which are themselves less common than in other countries. Finland ranks highest in terms of both the prevalence of R&D departments and the expenditure incurred, while Poland is characterised by a moderate level of R&D expenditure among enterprises and a relatively low share of companies with an R&D department.

Figure 8.4. Enterprises with an R&D department on a permanent or occasional basis vs the share of R&D expenditure in total expenditure on innovation activity, 2020–2022



Source: own elaboration based on CIS 2022 data.

Figure 8.5. Declared R&D expenditure vs the introduction of product innovations among enterprises, 2020–2022



Source: own elaboration based on CIS 2022 data.

In the final step of the analysis, the extent to which measurable expenditure on R&D departments translates into the introduction of product innovation was examined, as illustrated in Figure 8.5.

A comparison between R&D expenditure per enterprise (expressed in EUR) between 2020 and 2022 and the percentage of enterprises reporting the introduction of product innovation indicates that a high level of financial outlay does not necessarily translate directly into more frequent implementation of innovation. Countries such as Denmark and Ireland, which have the highest levels of R&D expenditure among innovation-active enterprises (ranging from EUR 6 million to over 9 million per company during the period under review), do not simultaneously achieve the highest rates of product innovation, which remain at a moderate level of between 35% and 42%. This suggests that intensive funding for R&D may be driven by costly infrastructure, high wages in the research sector, or the activities of several large companies, but does not necessarily translate into widespread innovation activity at the level of the economy as a whole.

A completely different picture emerges in the group of countries with relatively low R&D expenditure but high product innovation activity. Romania, Slovenia, Portugal, Italy and Greece record some of the highest rates of declared product innovation implementation (50–58%), despite their R&D expenditure remaining at the level of several hundred thousand EUR per enterprise. This may indicate greater efficiency in the use of funds, lower costs of innovation implementation, or the predominance of simpler and less capital-intensive forms of product innovation.

It is also worth noting countries such as Poland, Lithuania, Estonia and Slovakia, which, with R&D expenditure ranging from EUR 500,000 to 1,100,000 per company, achieve moderate innovation rates (35–40%). This indicates that, although they invest more in R&D than southern European countries (in Poland, the average expenditure exceeds EUR 1 million), this translates to a limited extent into actual product innovation, at least in the group of enterprises surveyed.

The overall picture that emerges from the study is that the relationship between the level of financial expenditure and declared innovation activity is weak and non-linear, clearly suggesting that other factors also play an important role here.

8.7. Conclusions: Poland on the global innovation map

R&D is an important determinant of the innovativeness of the economy; therefore, in summarising the analyses presented in this chapter, which focus on the R&D sphere, it is worth taking a synthetic look at the outcomes of innovation processes. The overall picture of innovation and Poland's position in this area can be determined

on the basis of the rankings presented in the European Innovation Scoreboard (EIS) [European Commission, 2025] and the report entitled Global Innovation Index (GII) [WIPO, 2025]. According to these reports, Poland is characterised by a relatively moderate, yet gradually improving, level of innovation. However, an innovation gap still separates Poland from even moderately innovative EU countries, and even more so from the innovation leaders [Weresa, Kowalski, Rybacki, 2022; Lewandowska, Kowalski, Majcherek, Hegerty, 2024], which indicates that the country is experiencing long-term innovation stagnation [Jasiński, 2025].

According to the EIS 2025 report, Poland achieves 65.9% of the average EU innovation level, placing it among the emerging innovators and ranking it 23rd among EU Member States. Although the overall innovation index has improved from year to year, the pace of change is insufficient to enable Poland to climb the ranking of EU countries. The strengths shaping innovation in the Polish economy include industrial design and investments in the development of internet and cloud computing infrastructure, while the greatest weaknesses relate to the financing of innovative activities, including venture capital funds, and the innovativeness of small and medium-sized enterprises. Long-term trends include growing digital competences, increasing public investment in R&D, and improvements in selected areas of human capital. At the same time, however, stagnation – or even decline – can be observed in innovation implementation within the SME sector.

The ranking presented in GII 2025 provides an international perspective on Poland's innovativeness. It is based on the Global Innovation Index methodology and indicators. Poland ranks 39th globally (compared with 40th in 2024 and 41st in 2023) and 25th in Europe. Over the longer term (2020–2025), Poland fluctuated between 38th and 41st place, indicating a stable, albeit rather modest, position. At the same time, it can be observed that Poland performs better in terms of innovation outputs (36th place) than in terms of inputs (45th place), indicating a relatively strong ability to turn limited resources into results – a trend that has persisted for years. The reason for this situation is structural deficiencies, including, *inter alia*, insufficient R&D expenditure, the inadequate quality of institutions, and weak links between academia and business, which, in turn, translate into insufficient interactions within the innovation system. Nevertheless, Poland excels in areas such as industrial diversification, exports of creative industry goods, high employment intensity in knowledge-intensive sectors, and a gradual increase in scientific publications [WIPO, 2025].

In summary, despite a gradual increase in R&D expenditure and the development of human resources for science and technology, Poland remains locked into the category of moderate innovators and is making no significant progress towards the leading countries. Relatively greater improvement can be observed in terms of output innovation

indicators, whereas aspects of innovation capacity (on the input side), including *inter alia*, funding and the institutional environment, constitute significant constraints. Poland lies above the regression line that defines the relationship between inputs and outputs [WIPO, 2025], which means that the country generates relatively more innovation outputs than would be expected given the level of investment made. This indicates the economy's ability to make effective use of available resources and suggests that its innovativeness is based primarily on human capital and the technological activity of enterprises, while funding – including R&D expenditure – and the institutional system for R&D, science and technology, remain a weak link.

An analysis of regional R&D expenditure in Poland confirms a strong concentration of innovation activity in several metropolitan voivodeships (Mazowieckie, Małopolskie, Pomorskie and Dolnośląskie), which clearly exceed the national average in terms of both the scale of expenditure and its intensity in relation to GDP and the *per capita* level. Regions such as Śląskie and Wielkopolskie are characterised by high overall expenditure but more dispersed and moderate R&D intensity, indicating a broad industrial base with a lower share of the most advanced knowledge-intensive functions. Some of the eastern voivodeships (e.g. Lubelskie, Podkarpackie) achieve relatively favourable intensity indicators despite moderate *per capita* expenditure, suggesting the presence of specialised but narrower innovation niches. At the opposite end are regions with low expenditure and a low concentration of R&D initiatives (e.g. Lubuskie, Świętokrzyskie, Zachodniopomorskie), where the potential for knowledge absorption and commercialisation remains limited. In the context of development policy, this implies the need to simultaneously strengthen existing knowledge hubs and create pathways for accelerated innovation growth in peripheral regions.

At this point, it is worth referring to the results of the analysis of CIS data for 2020–2022, which relate to existing research infrastructure, the structure of innovation expenditure, and the introduction of product innovation.

First, the relationship between maintaining an R&D department and implementing innovation is positive but statistically insignificant, which means that the mere existence of an in-house R&D department, whether set up on an *ad hoc* basis or operating on a permanent basis, does not determine an enterprise's ability to generate a new product. This conclusion also applies to entities from Poland.

Second, maintaining R&D departments is associated with a higher intensity of investment in research and development; however, this correlation is not strong, either. In this respect, Poland falls within the group of countries characterised by an average correlation between R&D structure and actual expenditure.

Third, a comparison of R&D expenditure per enterprise with the percentage of companies introducing product innovation confirms that even high expenditure does

not necessarily lead to greater innovation activity. In many of the countries with the highest expenditure – such as Denmark or Ireland – a significant portion of funds may be allocated to costly basic research, infrastructure development or highly complex projects that do not generate immediate market results. At the same time, Denmark typically ranks among the leading EU countries in terms of innovation performance. Furthermore, R&D activities are characterised by a natural time lag between the moment expenditure is incurred and the emergence of innovative outcomes. Consequently, a high level of investment in research and development often reflects only the initial stage of the innovation cycle, while visible implementation indicators may not appear until subsequent years.

References

Chesbrough, H. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Ciborowski, R. (2012). Region jako źródło wiedzy i innowacji. In: *Między ekonomią a historią. Studia ofiarowane profesorowi Czesławowi Noniewiczowi z okazji jubileuszu 75. urodzin* (pp. 464–476), R. Dziemianowicz, A. Kargol-Wasiluk, J. Wilkina, M. Zalesko (Eds.). Białystok: Wydawnictwo Uniwersytetu w Białymstoku.

Cowan, R., Jonard, N., Zimmermann, J.B. (2004). On the Creation of Networks and Knowledge. In: *The Complex Dynamics of Economic Interaction. Lecture Notes in Economics and Mathematical Systems* (Vol. 531, pp. 337–353), M. Gallegati, A.P. Kirman, M. Marsili (Eds.). Berlin–Heidelberg: Springer. DOI: 10.1007/978-3-642-17045-4_20.

Edquist, C. (1997). Systems of Innovation Approaches – Their Emergence and Characteristics. In: *Systems of Innovation: Technologies, Institutions, Organizations* (pp. 1–35), C. Edquist (Ed.). London–Washington: Pinter.

European Commission (2025). *European Innovation Scoreboard 2025*. Luxembourg: Publications Office of the European Union. DOI: 10.2777/3239776.

Eurostat (2025). *Glossary: Human Resources in Science and Technology (HRST)*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Human_resources_in_science_and_technology_ (HRST) (accessed: 14.11.2025).

Fischer, M.M. (1999). The Innovation Process and Network Activities of Manufacturing Firms. In: *Innovation, Networks and Localities* (pp. 11–27), M.M. Fischer, L. Suarez-Villa, M. Steiner (Eds.). Berlin: Springer.

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Statistics Poland (2024). *Działalność badawcza i rozwojowa w Polsce w 2023 r.* Warszawa–Szczecin: Statistics Poland.

Statistics Poland (2025). *Nauka i technika. Społeczeństwo informacyjne*, https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/spoleczenstwo-informacyjne/spoleczenstwo-informacyjne-w-polsce-w-2025-r-,2,15.html?contrast=default (accessed: 20.10.2025).

Jasiński, A.H. (2025). Innowacyjność przedsiębiorstw przemysłowych w latach 2015–2022. Mierniki i ocena w Polsce, *Gospodarka Narodowa. The Polish Journal of Economics*, 321(1), pp. 68–83. DOI: 10.33119/GN/194055.

Kleinknecht, A., Verspagen, B. (1990). Demand and Innovation: Schmookler Re-Examined, *Research Policy*, 19(4), pp. 387–394. DOI: 10.1016/0048-7333(90)90022-X.

Kline, S.J., Rosenberg, N. (1986). An Overview of Innovation. In: *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–305), R. Landau, N. Rosenberg (Eds.). Washington: National Academy Press.

Kowalski, A.M. (2022). Regional Approach to Innovation and the Role of Clusters. In: *The Dynamics of the Innovation Divide Between China and Europe: National and Regional Dimensions* (pp. 21–47), A.M. Kowalski (Ed.). London: Routledge. DOI: 10.4324/9781003199052.

Lewandowska, M.S., Kowalski, A.M., Majcherek, D., Hegerty, S.W. (2024). Regional Economic, Social and Healthcare Disparities Among the European Union Member States. In: *Economic Development and Resilience by EU Member States* (pp. 47–66), S. Grima, I. Romānova, G.G. Noja, T. Dorożyński (Eds.). Leeds: Emerald Publishing Limited. DOI: 10.1108/S1569-375920240000115004.

Lundvall, B.A. (Ed.). (1992). *National Systems of Innovations: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.

Mankiw, N.G., Romer, D., Weil, D.N. (1992). A Contribution to the Empirics of Economic Growth, *The Quarterly Journal of Economics*, 107, pp. 407–437. DOI: 10.2307/2118477.

Nelson, R., Rosenberg, N. (1993). Technical Innovation and National Systems. In: *National Innovation Systems: A Comparative Study* (pp. 3–22), R. Nelson (Ed.). New York: Oxford University Press.

Rothwell, R. (1994). Towards the Fifth-Generation Innovation Process, *International Marketing Review*, 11(1), pp. 7–31. DOI: 10.1108/02651339410057491.

Schmookler, J. (1965). Technological Change and Economic Theory, *American Economic Review*, 55 (1/2), pp. 333–341.

Schumpeter, J.A. (1912). *Theorie der Wirtschaftlichen Entwicklung*. Leipzig: Duncker und Humbolt.

Smith, D. (2010). *Exploring Innovation*. London: McGraw-Hill.

Weresa, M.A., Kowalski, A.M., Rybacki, J.P. (2022). Towards Convergence in National and Regional Innovation Performance: The Case of Selected EU Countries. In: *The Dynamics of the Innovation Divide Between China and Europe: National and Regional Dimensions* (pp. 71–111), A.M. Kowalski (Ed.). London: Routledge.

WIPO (2025). *Global Innovation Index 2025: Innovation at a Crossroads*, https://www.wipo.int/web-publications/global-innovation-index-2025/en/index.html (accessed: 15.01.2026).

Chapter 9

Research and Development as a Driver of Innovation in Small and Medium-Sized Enterprises in the European Union

Dawid Majcherek, Aleksandra Kubecka

9.1. Introduction

The contemporary economy of the European Union is characterised by increasing competitiveness, the dynamic globalisation of markets, and growing technological pressure, which means that the ability to generate and implement innovation is a key factor in ensuring that enterprises maintain a sustainable competitive advantage. Particular attention should be devoted here to product innovation – understood as the introduction of new or significantly improved products – which constitutes not only a source of increased added value but also a prerequisite for companies to maintain competitiveness in international markets. In this context, research and development (R&D) activities assume particular importance, as they are widely recognised as the primary driver of innovation processes, enabling the creation of new knowledge, the development of technologies, and the improvement of the product offering.

Although the key role of research and development in building innovation capacity has been repeatedly confirmed in the scientific literature, empirical studies indicate that the effectiveness of R&D investment may vary depending on the type of enterprise, its business profile, and the market environment. In particular, enterprises operating in international markets are often characterised by a greater propensity to invest in technological development and by more intensive organisational learning processes. At the same time, companies focusing on the domestic market may adopt different innovation strategies, based, for example, on adapting existing solutions or utilising technology transfer [Statistics Poland, 2020; Chyba, Kacprzak, 2019; OECD, 2015]. Understanding these differences is important both from the perspective of EU economic policy aimed at strengthening the economy's innovation potential and from the perspective of enterprise strategies designed to enhance competitiveness.

R&D constitutes one of the key mechanisms for building the innovativeness of small and medium-sized enterprises (SMEs) in the EU, as it strengthens the ability of companies to create and adapt new solutions and to absorb knowledge from their environment. At the "innovation stage", cooperation among the various actors – enterprises, the science sector and the state – is of fundamental importance. Only when their activities complement one another can lasting innovation outcomes be achieved, which is particularly important for SMEs with their limited in-house resources and competences [Jasiński, 2021]. Empirical studies on Poland show that the innovativeness of enterprises varies significantly across industries and over time, and that measures of innovation activity remain sensitive to access to finance, human resources and collaborative links, which indirectly explains why SMEs are more likely to choose to conduct R&D activities in collaboration with other entities than in a fully in-house model [Jasiński, 2025]. At the same time, statistical data indicate an increasing volume of expenditure on research and development and the importance of the business sector in carrying out such activities [Statistics Poland, 2022]. From an economic policy perspective, it is significant that, although the percentage of companies implementing innovations is increasing, the uptake of public support – primarily allocated to R&D – can be relatively low. This suggests the need for better alignment of such instruments to the specific characteristics of SMEs. The literature also emphasises that in countries catching up with the EU (such as Poland), increasing SME innovativeness requires reducing institutional barriers and strengthening collaboration with academia, especially at the stage of implementing R&D projects [Oksanych, 2019].

This chapter analyses the role of R&D as a factor determining the likelihood of introducing product innovations in European small and medium-sized enterprises. For this purpose, microdata from the Community Innovation Survey (CIS) 2018 covering the years 2016–2018 and encompassing 100,115 business entities operating in the EU were used, making it possible to capture the diversity of innovation determinants across a wide range of sectors and countries and to conduct an analysis with exceptionally high statistical power. To estimate the impact of R&D and other determinants on the introduction of innovations, logistic regression models were used, enabling the probability of implementing product innovations depending on the presence of specific characteristics of the enterprise. The results are presented in the form of odds ratios, which facilitates clear interpretation of the scale of the impact of individual factors. In addition, principal component analysis (PCA) was used to aggregate variables related to collaboration of companies with the innovation environment, making it possible to synthetically capture complex network relationships.

The analysis was conducted not only for the full sample of SMEs, but also separately for exporters and non-exporters, which allowed for identification of differences

in the mechanisms for generating innovation depending on the market orientation of the enterprises. This approach enables a more precise determination of whether the impact of R&D investment on product innovation differs between exporting and non-exporting SMEs, and whether companies operating exclusively in domestic markets pursue alternative innovation pathways**.** Accordingly, the following research questions were formulated:

1) To what extent do R&D activities increase the likelihood of introducing product innovations in small and medium-sized enterprises (SMEs) in the EU?
2) Does a company's export orientation alter the impact of R&D activities on its ability to implement product innovations?
3) What role does collaboration with the innovation environment play in the innovation process, and to what extent is it complementary to R&D activities?

9.2. Research and development as a source of innovation

Even in classical approaches, it was pointed out that investment in R&D enhances companies' ability to both generate and absorb knowledge, which directly translates into the development of innovation [Griliches, 1998; Cohen, Levinthal, 1990]. The literature on the subject also emphasises that R&D constitutes not only a source of innovation but also a prerequisite for building long-term technological competencies and competitive advantage [Hall, Mairesse, Mohnen, 2010; Teece, 1986; Utterback, 1994].

The concept of absorptive capacity suggests that R&D is not an isolated process, but rather strengthens a company's ability to identify, assimilate and use knowledge from its environment [Cohen, Levinthal, 1990]. Empirical studies confirm that companies with higher R&D intensity achieve superior innovation performance [Hall et al., 2010], although this relationship may be non-linear, with diminishing returns at excessively high levels of expenditure [Love, Roper, 2015; Dong, Wei, Liu, Xing, 2020].

The literature on open innovation emphasises that internal investment in R&D is complementary to external sources of knowledge [Laursen, Salter, 2006; Berchicci, 2013; Song, Kim, 2024]. Companies with developed research capabilities benefit more effectively from collaboration, generating synergies between the processes of knowledge internalisation and exploration [Criscuolo, Nicolaou, Salter, 2012]. At the same time, financial constraints can hinder investment in R&D, particularly among small and medium-sized enterprises [Czarnitzki, Hottenrott, 2011], which underscores the role of public policy instruments in supporting innovation activities.

The triple helix model developed by Etzkowitz and Leydesdorff [1995] posits that innovation is the result of collaboration between businesses, the research sector, and the state. In the quadruple helix model, Carayannis and Campbell [2009] expand this approach to include an additional dimension of civil society, encompassing the media and culture, and emphasise its role in supporting innovation processes. Collaboration in R&D activities provides access to partners' resources, risk and knowledge [Gnyawali, Srivastava, 2013; Fleming, 2001], which in turn strengthens the organisation's dynamic capabilities [Cillo, Rialti, Bertoldi, Ciampi, 2021; Teece, Pisano, Shuen, 1997].

Empirical studies confirm the importance of partnership in innovation processes. Cassiman and Veugelers [2002] demonstrated that collaboration in R&D activities generates a spillover effect that increases absorptive capacity. Belderbos, Carree and Lokshin [2004] defined different objectives for collaboration depending on the type of partner: in interactions with competitors and suppliers, incremental improvement effects predominate, whereas collaboration with universities and research institutions fosters groundbreaking innovations. The structure and topology of the collaboration network determine the effectiveness of knowledge flows and innovation [Filho, O'Neale, 2020]. The effectiveness of collaboration itself also depends on the cultural context [Zhang, Wang, Duan, 2019].

Innovation processes are complementary in nature, with a synergy effect arising when different activities reinforce each other [Topkis, 1978; Milgrom, Roberts, 1995; Hitt, Ireland, Hoskisson, 2007]. Research illustrates that simultaneous pursuit of product, process and organisational innovations increases the efficiency of companies [Evangelista, Vezzani, 2010; Martinez-Ros, Labeaga, 2009; Ballot, Fakhfakh, Galia, Salter, 2015]. Complementarity stands out as particularly important for smaller enterprises, where the integration of process and product activities can determine competitiveness [Kamutando, Tregenna, 2024].

New technologies often require the acquisition of resources from outside the company [Maffei, Meredith, 1995; Teece et al., 1997], and successful implementation depends on organisational competence, process flexibility and the ability to learn [Dosi, 1988; Burns, Stalker, 1961]. The dynamic capabilities perspective posits that companies need not only to acquire technologies, but also develop the ability to absorb and adapt them [Teece et al., 1997].

A substantial body of research focuses on the learning-by-exporting mechanism, according to which a presence in international markets fosters the accumulation of knowledge and innovation [Grossman, Helpman, 1991; Mińska-Struzik, 2014]. Interactions with foreign customers, competitors and research partners enable companies to imitate, adapt and develop their own innovations [Rhee, Ross-Larson, Pursell, 1984; Keller, 2004]. Empirical studies indicate that exports increase the productivity

of companies [De Loecker, 2013], although the outcomes they achieve also depend on their ability to plan activities and implement organisational innovations [Juergensen, Love, Surdu, Narula, 2024].

9.3. Research methods

The presented analysis was conducted based on the Community Innovation Survey (CIS) conducted by Eurostat. The CIS is one of the most important sources of data on the innovation activity of companies in Europe, collecting detailed information on, *inter alia*, implemented innovations, R&D expenditure, innovation-related collaboration, and the use of support instruments. Subsequent editions of the survey are conducted every two years, and since 2018, the methodology has followed the guidelines outlined in the fourth edition of the *Oslo Manual*, which expanded the scope of the examined innovation-related phenomena compared to its previous versions [Statistics Poland, 2020]. Although reporting data on innovation in the EU is mandatory for all Member States (pursuant to Commission Implementing Regulation (EU) 2020/1197 of 30 July 2020 laying down technical specifications and arrangements pursuant to Regulation (EU) 2019/2152 of the European Parliament and of the Council on European business statistics repealing 10 legal acts in the field of business statistics) [Statistics Poland, 2025], not all of the 27 EU Member States make anonymised CIS microdata available for scientific purposes via Eurostat. Poland is among the countries that do not provide such access.

The study uses data from the most recent available (at the time of writing) edition of the CIS 2018 survey, covering the years 2016–2018 and encompassing 100,115 enterprises from 14 EU countries operating in various sectors of the economy. The analysis covered all available groups of economic activities according to the NACE Rev. 2 classification (sections A–P), corresponding to the Polish PKD 2007 classification. The sample used in the study comprised 83,500 entities from the small and medium-sized enterprise (SME) sector from 11 EU countries, for which it was possible to identify individual companies within this category. Micro-enterprises were not included in the sample because the CIS microdata do not contain observations for this category of enterprises. The structure of the sample is illustrated in Table 9.1.

Due to the binary nature of the dependent variable – indicating whether a company introduced a product innovation – logistic regression models were used, enabling the estimation of the impact of explanatory factors on the probability of innovation, taking into account not only the direction of the impact but also its magnitude.

Table 9.1. Structure of the surveyed SME sample

Country	Number of observations	Share (%)
Bulgaria	14,967	17.9
Croatia	2,421	2.9
Czech Republic	4,524	5.4
Greece	3,758	4.5
Spain	27,417	32.8
Lithuania	2,086	2.5
Germany	4,769	5.7
Portugal	7,634	9.1
Romania	6,442	7.7
Slovakia	2,802	3.4
Hungary	6,680	8.0
Total	83,500	

Source: own elaboration based on CIS 2018 data [Eurostat, 2021].

The results of the models are presented in the form of odds ratios (OR), providing an intuitive interpretation of the effects. OR values greater than 1 indicate that a variable increases the probability of implementing a product innovation, while OR values below 1 indicate a negative effect. These types of measures are widely used in economic and social research, particularly when the aim is to identify factors that determine the behaviour of enterprises, rather than merely provide a statistical description.

To reduce model complexity and eliminate the problem of collinearity, principal component analysis (PCA) was used to aggregate the variables related to collaboration with the innovation environment. As a result, seven factors describing relationships with different types of partners were transformed into synthetic components that effectively reflect the structure of collaboration. This approach made it possible to comprehensively examine the importance of innovation networks in the process of generating innovation while maintaining the transparency of the models and improving their estimation stability.

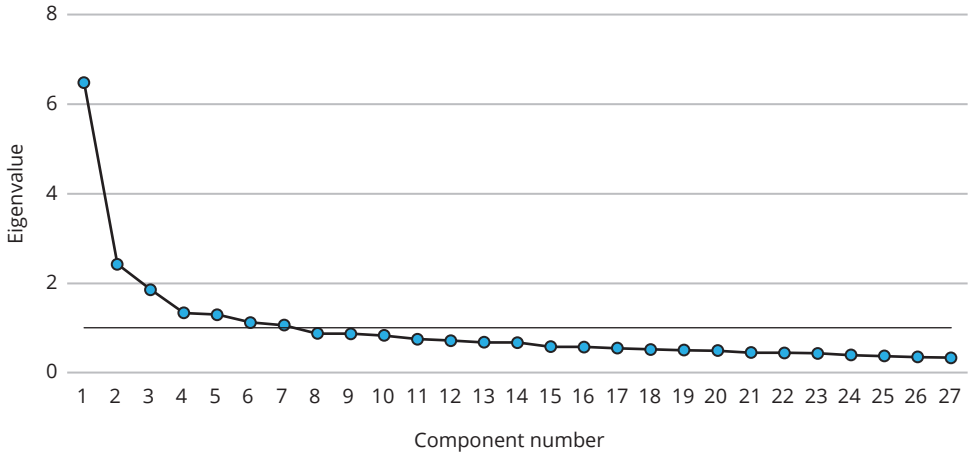
Furthermore, the analyses were conducted both for the entire SME sample and separately for exporters and non-exporters, which made it possible to identify differences in innovation mechanisms depending on the market orientation of companies.

9.4. Results of the principal component analysis

One of the key factors that can influence the implementation of innovation is cooperation undertaken by enterprises in this area. Consequently, the question concerning cooperation partners for innovation activity constitutes one of the core questions in the CIS and is included in every edition of the survey conducted to date. In the 2018 CIS survey, question 3.16 ("please indicate the type of innovation co-operation partner by location") offered six response categories (one of which was further divided into five subcategories), classified according to the country of origin of the co-operation partner (domestic partners, partners from EU/EFTA countries, and partners from outside the EU/EFTA). The variables describing collaboration were binary in nature.

Given the large number of variables created in this way, describing collaboration in innovation activities, as well as the missing data in the question, it was decided – before incorporating collaboration into the main part of the analysis using logistic regression – to attempt to apply principal component analysis (PCA) to reduce the dimensions of the variables related to collaboration while maintaining a valid data structure. The PCA method is an exploratory data analysis technique and, unlike confirmatory analysis, allows for the analysis of data with an unknown structure [Bedyńska, Cypryańska, 2013]. The analysis employed PCA with Varimax rotation (with Kaiser normalisation).

Figure 9.1. Scree plot for the PCA



Source: own elaboration based on CIS 2018 data [Eurostat, 2021].

Before proceeding with the analysis, three variables relating to entities outside the capital group of the surveyed company[1] were excluded due to numerous data gaps. In the course of the factor analysis, a further three variables were eliminated due to their low factor loading[2] (less than 0.5). Based on the scree plot criterion (Figure 9.1) and the eigenvalue (greater than 1), seven components were ultimately identified, together explaining 61.3% of the variance in the results.

Based on the PCA conducted in SPSS (on a sample of SMEs), seven factors that describe collaboration in innovation activity were identified according to the key partner in this collaboration:

1) domestic partners (excluding competitors),
2) foreign suppliers of equipment, materials, components or software, as well as foreign customers,
3) foreign public-sector institutions from outside the EU/EFTA (governmental or public research institutes, universities or other higher education institutions, non-profit organisations from outside the EU/EFTA),
4) foreign public-sector institutions from the EU/EFTA (governmental or public research institutes, universities or other higher education institutions from the EU/EFTA),
5) other foreign public-sector institutions from the EU/EFTA (public-sector customers or clients, non-profit organisations from the EU/EFTA),
6) competitors (regardless of the country of establishment),
7) enterprises belonging to the same capital group as the surveyed company and located abroad (both within and outside the EU/EFTA).

These factors were subsequently incorporated in the logistic regression model used to analyse the determinants of product innovation in European SMEs.

9.5. Results of logistic regression models for product innovations

The aim of the analysis was to examine the determinants of the probability of implementing product innovations in European SMEs, with particular emphasis on R&D expenditure. The study used data from the CIS survey. The dependent variable was a binary variable indicating the introduction of a product innovation, while the set of explanatory variables related both to factors of innovation activity identified

[1] The variables excluded from the analysis are: COOP_PRV_OTH_NAT, COOP_PRV_OTH_EU_EFTA COOP_PRV_OTH_NEU_NEFTA [Eurostat, 2021].

[2] COOP_EG_NAT, COOP_PRV_CN_NEU_NEFTA, COOP_PRV_CN_NEU_NEFTA [Eurostat, 2021].

in the literature – including R&D expenditure – and to other determinants (such as technology purchases, R&D expenditure, and the use of intellectual property assets), as well as to external factors, in particular links with domestic and foreign partners and the availability of public funding. The model was estimated for the entire SME sample and separately for exporters and non-exporters, with a view to subsequently identifying differences in the determinants of innovation between these groups. Table 9.2 lists the variables that were taken into account in the subsequent modelling.

Table 9.2. Variables used in the logistic regression model

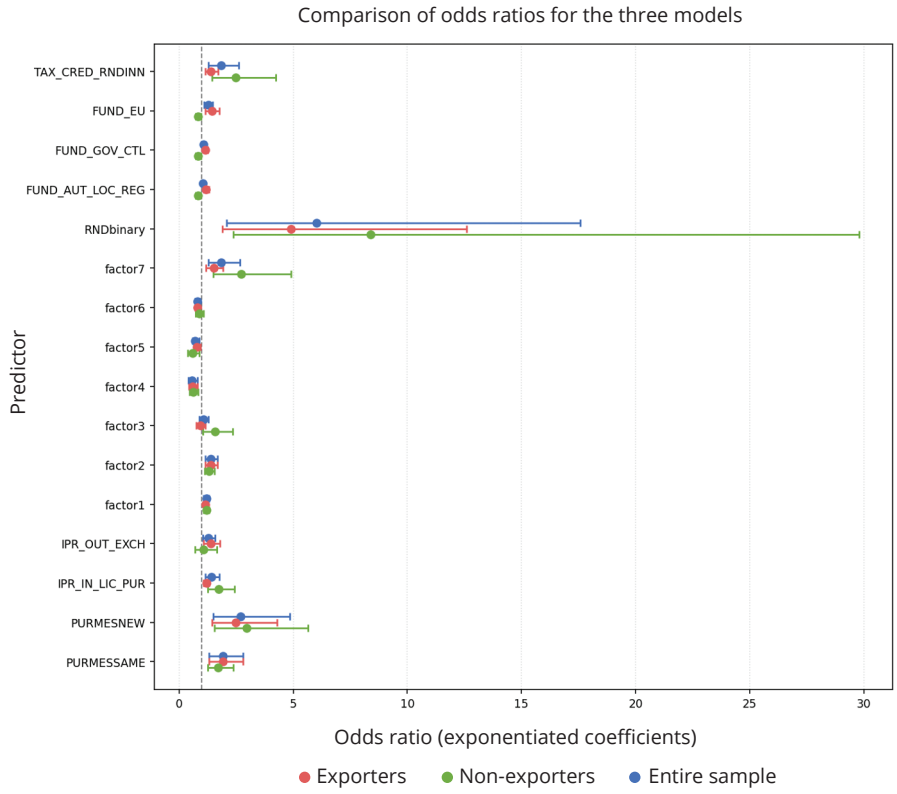
No.	Variable name	Variable description
Dependent variable		
	ProductInnovation	binary dependent variable; takes the value 1 if the company has introduced a product innovation, or 0 if it has not
Explanatory variables		
1	*FUND_EU*	public financial support from the European Union (Horizon 2020 and other programmes) – binary variable; takes the value 1 if the company has received such support, or 0 otherwise
2	*FUND_GOV_CLT*	public financial support from central government entities – binary variable; takes the value 1 if the company has received such support, or 0 otherwise
3	*FUND_AUT_LOC_REG*	public financial support from local government or regional government administration bodies – binary variable; takes the value 1 if the company has received such support, or 0 otherwise
4	*TAX_CRED_RNDINN*	use of tax incentives or tax reliefs for R&D or other innovative activities – binary variable; takes the value 1 if the company has benefited from such incentives or reliefs, or 0 otherwise
5	*PURMESSAME*	purchase of machinery, equipment or software using new technology not previously used in the company – binary variable; takes the value 1 if the company has made such a purchase, or 0 otherwise
6	*PURMESNEW*	purchase of machinery, equipment or software using technology previously used or modernised by the company – binary variable; takes the value 1 if the company has made such a purchase, or 0 otherwise
7	*IPR_IN_LIC_PUR*	purchase or licensing of patents or other intellectual property rights (all sources) – binary variable; takes the value 1 if the company has made such a purchase, or 0 otherwise
8	*IPR_OUT_EXCH*	exchange of intellectual property rights, pooling, cross-licensing – binary variable; takes the value 1 if the company has made such an exchange, or 0 otherwise
9	*RNDbinary*	expenditure on R&D activities carried out within the entity (share of total expenditure) – binary variable; takes the value 1 if the company has incurred such expenditure, or 0 otherwise
10–16	*factor1–factor7*	seven factors representing the company's partnership in innovation cooperation, as determined by the PCA (described above)

cont. Table 9.2

No.	Variable name	Variable description
Grouping variable		
	exportEUEFTA + *exportnonEUEFTA*	percentage of revenue from sales of products to foreign customers from EU and EFTA countries and from outside the EU and EFTA in 2018 – a binary variable used to distinguish exporters from non-exporters; takes the value 1 if revenue from sales of products abroad has been reported, or 0 otherwise

Source: own elaboration based on Eurostat [2021].

Figure 9.2. Impact of determinants on the probability of implementing product innovations



Source: own elaboration based on anonymised Eurostat microdata (CIS 2018), made available for the purposes of scientific research under RPP 199/2023-CIS.

The data presented in Table 9.3 indicate that the strongest determinant of the implementation of product innovations is expenditure on in-house R&D activities (*RNDbinary*). Overall, the OR is 6.03; among exporters, it amounts to 4.89; while in the group of non-exporters, it reaches as much as 8.39. These results indicate that

R&D expenditure increases the probability of product innovations seven-fold, leaving no doubt that in-house R&D potential is a key mechanism for fostering innovation. The exceptionally high probability of product innovations in non-exporting companies suggests that, within this group, engaging in R&D is a more selective strategy – adopted by a smaller number of companies but more strongly determining their ability to create product innovations.

Table 9.3. Results of logistic regression models: odds ratio (OR) estimates for the introduction of product innovations – a comparative analysis of exporters and non-exporters

	Entire sample		Exporters		Non-exporters	
Predictors	OR	*p*	OR	*p*	OR	*p*
(Intercept)	0.07	**<0.001**	0.09	**<0.001**	0.05	**<0.001**
factor1	1.19	**<0.001**	1.16	**<0.001**	1.19	**<0.001**
factor2	1.38	**<0.001**	1.38	**<0.001**	1.32	**<0.001**
factor3	1.07	0.474	0.94	0.567	1.57	**0.026**
factor4	0.56	**<0.001**	0.58	**<0.001**	0.61	**<0.001**
factor5	0.71	**<0.001**	0.78	**0.010**	0.58	**0.011**
factor6	0.80	**<0.001**	0.80	**<0.001**	0.89	0.237
factor7	1.85	**<0.001**	1.51	**<0.001**	2.71	**<0.001**
FUND_AUT_LOC_REG	1.04	0.215	1.18	**<0.001**	0.83	**0.006**
FUND_EU	1.27	**<0.001**	1.43	**<0.001**	0.83	**0.008**
FUND_GOV_CTL	1.07	**0.040**	1.16	**<0.001**	0.83	**0.009**
IPR_IN_LIC_PUR	1.42	**<0.001**	1.19	**<0.001**	1.74	**<0.001**
IPR_OUT_EXCH	1.28	**0.023**	1.39	**0.010**	1.08	0.722
PURMESNEW	2.69	**<0.001**	2.49	**<0.001**	2.96	**<0.001**
PURMESSAME	1.91	**<0.001**	1.91	**<0.001**	1.72	**<0.001**
RNDbinary	6.03	**<0.001**	4.89	**<0.001**	8.39	**<0.001**
TAX_CRED_RNDINN	1.83	**<0.001**	1.40	**<0.001**	2.47	**<0.001**
Number of observations	100,115		48,719		48,843	
Tjur's R^2	0.250		0.254		0.197	

Source: own elaboration based on anonymised Eurostat microdata (CIS 2018), made available for the purposes of scientific research under RPP 199/2023-CIS.

The purchase of new machinery, equipment and software constitutes one of the most important predictors of the implementation of product innovations. In particular, the acquisition of technologies that are new to the company (*PURMESNEW*) significantly increases the likelihood of innovation across all models (OR of 2.69 in the overall sample, 2.49 among exporters, and as high as 2.96 among non-exporters). These

results indicate that technological upgrading of technical facilities is one of the key mechanisms for introducing new products. Significantly, this effect is even stronger among non-exporters, suggesting that such companies more often rely on the transfer of ready-made technologies as their primary means of generating innovation than on their own R&D activities. The purchase of machinery based on technology already in use (*PURMESSAME*) also significantly increases the likelihood of implementing innovations (OR ≈ 1.91 in all groups). Although the effect is weaker here than in the case of investments in new technologies, the obtained result highlights the importance of modernising production infrastructure, including in terms of existing solutions, which may enable the development of incremental product innovations.

The use of external intellectual property (IP) resources also exerts a significant effect. The purchase of licences and patents (*IPR_IN_LIC_PUR*) increases the likelihood of innovation in all groups, particularly among non-exporters (OR = 1.42), confirming their greater reliance on off-the-shelf technological solutions. The exchange of intellectual property rights (*IPR_OUT_EXCH*) is statistically significant in the full sample and among exporters (ORs of 1.28 and 1.39, respectively), but does not achieve statistical significance among non-exporters, indicating that complex IP cooperation mechanisms are the domain of enterprises with stronger international market involvement.

The results relating to the seven factors representing companies' collaboration with various partners confirm that external links are a key component of the innovation ecosystem, although their importance varies depending on the type of partner and the company's market orientation.

Collaboration with enterprises belonging to the same capital group as the surveyed company and located abroad (*factor7*) exerts the strongest positive effect on the likelihood of innovation across all groups, particularly among non-exporters (OR = 2.71, implying a 171% increase in the probability of product innovation). This may indicate the effects of know-how transfer and the use of resources and technologies of international groups, compensating for the lack of direct exposure to foreign markets.

The second most significant positive effect is observed in the case of collaboration with foreign suppliers (of equipment, materials, components or software) and foreign customers (*factor2*). Such collaboration significantly increases the probability of implementing innovations across all analysed groups (OR ranging from 1.32 to 1.38), indicating that the likelihood of introducing a product innovation is approx. 30% higher when collaborating with foreign suppliers. This result confirms the key role of domestic research and development infrastructure as a source of knowledge and technology, regardless of a company's international engagement.

Collaboration with domestic partners (excluding competitors, *factor1*) also significantly promotes innovation, particularly among non-exporters (OR = 1.19). This

finding suggests that, for enterprises operating on the domestic market, direct interaction with national partners constitutes one of the main sources of innovation stimuli.

Interesting results were obtained with regard to collaboration with foreign public-sector institutions from the EU/EFTA (governmental or public research institutes, universities or other higher education institutions from the EU/EFTA, *factor4*). OR values below 1 (0.56–0.61) indicate that companies collaborating with competitors are less likely to implement product innovations, although this negative effect is the weakest among non-exporters. This may suggest that collaboration with competitors is more focused on standardisation or cost-related areas than on creative aspects, or that it is used by firms pursuing imitative strategies rather than companies undertaking pioneering projects.

Collaboration with other foreign public institutions in the EU/EFTA (*factor5*) and with competitors, regardless of the country (*factor6*), shows varied effects – *factor5* reduces the probability of innovation by 42% (especially for non-exporters, OR = 0.58), whereas *factor6* is significant only for exporting companies and the overall sample, but with a small negative effect (OR = 0.78). These findings suggest that formal international public partnerships have limited effectiveness in generating product innovations, potentially due to their administrative and bureaucratic nature.

Access to public funding exerts a differentiated impact on innovation. Local and regional funding (*FUND_AUT_LOC_REG*) supports the implementation of product innovations only among exporters (OR = 1.18), whereas for non-exporters the impact of this factor is negative (OR = 0.80). This may suggest that local programmes provide more effective support for companies with greater innovation potential and a more developed project infrastructure.

EU funding (*FUND_EU*) significantly promotes innovation among exporters (OR = 1.43), although it reduces the likelihood of product innovation being implemented by non-exporters (OR = 0.74). This finding may reflect the selectivity and formal complexity of EU programmes, which are used most effectively by enterprises operating on international markets. A similar effect can be observed for domestic funding (*FUND_GOV_CTL*).

The Tjur's R^2 index, which measures the model's ability to distinguish between innovative and non-innovative cases, reached a value of 0.25 for the entire sample, 0.254 for exporters and 0.197 for non-exporters. These results suggest that the model possesses moderate predictive power. At the same time, the findings point to a markedly greater understanding of innovation mechanisms among exporters, indicating more coherent and identified innovation processes within these companies, as well as a greater role of measurable, observable factors in determining their development strategies. For non-exporters, the explanatory power of the model is lower, which may indicate

that other factors not included in the study – such as behavioural motivations, the specificity of market niches, or informal cooperation – play a more important role.

The analysis confirms the significant impact of investment in R&D activities and the purchase of technology as the main determinants of product innovation. Links with the environment – both business and institutional – prove to be equally important, although their impact varies depending on the type of partner. The results also indicate a clear heterogeneity between exporters and non-exporters. Exporting companies are characterised by more predictable innovation mechanisms and greater efficiency in the use of public instruments and international cooperation, while in the case of non-exporting companies, the creation of innovations is more often dependent on technology transfer than on advanced forms of collaboration, suggesting a more imitative orientation of their innovation strategies.

9.6. Discussion of results

The empirical results obtained confirm that the ability of European SMEs to generate product innovations is primarily determined by three types of activities: allocating resources to R&D, investing in the purchase of new technology, and modernising existing technological solutions. Together, these findings suggest that innovation in the EU continues to be based on the logic of complementary development of in-house research capabilities and the absorption of third-party technologies. This interpretation is consistent with the classic concept of absorptive capacity [Cohen, Levinthal, 1990], according to which investments in R&D serve not only to create new solutions but also to develop the ability to effectively assimilate technologies and knowledge available on the market.

At the same time, the research findings reveal an interesting asymmetry between exporting enterprises and those operating primarily on the domestic market. Among non-exporting companies, the impact of R&D activities is clearly stronger, which may be due to the fact that the decision to invest in R&D is more common among entities that are already technologically advanced and possess greater organisational capabilities. Consequently, non-exporters investing in R&D may represent a more select group, within which research activity is a deliberate strategy to build an advantage in the domestic market in response to the lack of competitive impetus from international markets. This observation is consistent with the classic learning-by-exporting approach [Rhee et al., 1984; Keller, 2004], which posits that a company can also "learn" without engaging in foreign expansion, provided that it possesses sufficiently developed knowledge resources and makes deliberate investments in technological development.

A similar relationship can be observed in the case of technology acquisition and technological upgrading of existing solutions. Although across all the models analysed, technology acquisition significantly increased the likelihood of implementing product innovations, these effects were clearly stronger in the group of non-exporters. This suggests that enterprises operating exclusively in domestic markets are more likely to use external sources of innovation and commercially available technologies, viewing these as their main channel for improving their operations. The findings of this study differ from those of research on technology transfer, which typically highlights a higher intensity of technology adaptation among international companies [Cassiman, Veugelers, 2002]. However, our findings indicate that technology transfer may serve as a compensatory mechanism for domestic companies, enabling them to remain competitive despite their limited exposure to global knowledge stimuli.

An even more unequivocal confirmation of this thesis is provided by the strong impact of capital links with foreign corporate groups among non-exporters. In their case, the benefits of participating in international capital structures – namely access to technology, organisational knowledge, and management processes – were greater than among exporting companies. This finding is consistent with the current debate on the role of foreign direct investment as a vehicle for technological knowledge [Keller, 2004], while also leading to an additional conclusion: for non-exporting companies, collaboration with a foreign investor constitutes a particularly important channel for technological upgrading, and thus a substitute for the effects that exporters obtain through market exposure.

Exporting enterprises, in turn, derive relatively greater benefits from public pro-innovation support – whether regional, national, or EU-wide – as well as from more advanced forms of technological cooperation, such as the exchange of intellectual property rights. This can be interpreted in two ways. First, exporters typically have a more developed organisational infrastructure and administrative capabilities, which enables them to apply for public funding and manage development projects more effectively. Secondly, these enterprises are more likely to operate within international ecosystems and make more intensive use of formal knowledge transfer mechanisms, which is consistent with the findings of other authors on open innovation [Laursen, Salter, 2006]. In other words, exporters possess an advantage in terms of absorbing institutional support and utilising complex forms of technological cooperation, whereas non-exporters rely more heavily on in-house R&D competencies and the transfer of off-the-shelf technologies for their innovation.

It is worth noting that the results obtained do not fully support the simple dichotomy according to which exports "always" strengthen innovation capabilities [Melitz, Redding,

2021]. Instead, the findings point to the existence of two parallel and equally effective paths for the development of innovativeness, as illustrated in Table 9.4.

This developmental dualism can be embedded in the framework of resource theory and the concept of dynamic capabilities [Teece, 1986; Teece et al., 1997]: enterprises follow the innovation path that is consistent with their organisational capabilities, knowledge capital and access to external support. Consequently, operating as an exporter or a non-exporter does not represent different stages of development within a single path, but rather two distinct models for building innovativeness. From this perspective, SMEs can treat them as practical roadmaps for building a competitive advantage in the EU market: depending on their export orientation, they should either strengthen their capacity for absorbing funding and technological cooperation (the export path) or optimise modernisation through technology transfer and adaptation (the non-export path) in order to maximise innovation outcomes within the resource constraints they are faced with.

Table 9.4. Comparison of the innovation paths of exporters and non-exporters

Non-exporters	Exporters
▪ intensive R&D activity in a selective group of enterprises ▪ advantage of technological upgrading through technology acquisition ▪ strong impact of international capital networks	▪ better absorption of public funds ▪ established channels for formal technological collaboration ▪ benefits of intellectual property exchange

Source: own elaboration.

9.7. Conclusions

The study enables an assessment of the mechanisms that foster the development of product innovation in small and medium-sized enterprises operating in the EU. The results confirm that the innovativeness of companies in Europe is a multidimensional process based on the simultaneous use of internal resources, technological investments, and external sources of knowledge. The most important factor determining the implementation of innovation remains the conduct of in-house R&D activities. However, it can be observed that its effect is stronger among non-exporting companies, indicating a specific segmentation of the European innovation ecosystem. For locally operating entities, investment in research constitutes a strategy with a high level of selectivity: they use it less frequently, but more intensively and effectively, which suggests that embarking upon the path of endogenous technological development requires deliberate and focused effort.

The complementary role of technology acquired from the market was also confirmed. Investments in both new technological solutions and the modernisation of existing systems remain important drivers of innovation development, and their importance is particularly visible among domestically-oriented businesses. This points to a practice whereby non-exporting companies, more often than exporters, build an advantage by absorbing technology, using available solutions as a catalyst for product development. This model – more adaptive than creative – reflects the structure of many national markets in the EU, where incremental innovations predominate over groundbreaking ones.

By contrast, the role of the international environment and global innovation networks is clearly evident in the case of exporting companies. These entities make more frequent use of public support instruments – whether national, regional, or EU-wide – which indicates a greater ability to obtain and utilise funds for technological development. Exporters also participate more frequently in advanced forms of knowledge exchange, such as the transfer and exchange of intellectual property rights. This may result from their greater involvement in global knowledge markets and their participation in international collaboration networks, which strengthens their ability to commercialise new solutions.

Paradoxically, certain aspects of international cooperation – particularly those related to capital links with foreign groups – proved to be more beneficial for non-exporting companies. This may be explained by the fact that these entities gain access to knowledge and technology through their affiliation with a group, without having to compete independently in international markets. Consequently, they develop competitive advantage through intra-corporate networks, benefiting from the "technological umbrella" effect of parent entities.

The analysis conducted has certain limitations. First, the use of cross-sectional data makes it impossible to capture the full dynamics of innovation processes, which unfold over many years. Secondly, the use of declarative data may entail the risk of respondents' perception bias. Furthermore, the fact that Eurostat publishes innovation microdata with a certain delay (at the end of 2025, the latest available edition of the CIS survey was for the period 2016–2018) makes it impossible to analyse more recent trends. An additional limitation is the absence of data for Poland in the analysed dataset, as Polish CIS microdata have not been made available for scientific use through Eurostat since the inception of the survey. There is also a need for in-depth analyses of the barriers to innovation development, including shortages of specialists, limited access to finance, risk aversion, and the complexity of regulatory and support procedures.

In summary, this study confirms the existence of two innovation development paths among small and medium-sized enterprises in the EU: an internal model, based

on intensive investment in research and technology absorption, and a network model based on international links, public funding, and knowledge transfer. This dualism indicates that, depending on their market orientation, SMEs may consciously choose the innovation path that best suits their resources and competitive ambitions in the EU market. A competitive advantage can be built either through the modernisation and adaptation of technology or through intensified collaboration, internationalisation and advanced R&D processes. These findings not only confirm the existing literature on the subject but also demonstrate that a company's market orientation significantly differentiates the effectiveness of its various innovation strategies. This implies that innovation policies should be tailored to the heterogeneous needs of companies – both those operating in local markets and those operating in globalised knowledge networks.

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References

Ballot, G., Fakhfakh, F., Galia, F., Salter, A. (2015). The Fateful Triangle: Complementarities in Performance Between Product, Process and Organizational Innovation in France and the UK, *Research Policy*, 44(1), pp. 217–232. DOI: 10.1016/j.respol.2014.07.003.

Bedyńska, S., Cypryańska, M. (Eds.). (2013). *Statystyczny drogowskaz 1. Praktyczne wprowadzenie do wnioskowania statystycznego*. Warszawa: Wydawnictwo Akademickie SEDNO.

Belderbos, R., Carree, M., Lokshin, B. (2004). Cooperative R&D and Firm Performance, *Research Policy*, 33(10), pp. 1477–1492. DOI: 10.1016/j.respol.2004.07.003.

Berchicci, L. (2013). Towards an Open R&D System: Internal R&D Investment, External Knowledge Acquisition and Innovative Performance, *Research Policy*, 42(1), pp. 117–127. DOI: 10.1016/j.respol.2012.04.017.

Burns, T., Stalker, G.M. (1961). *The Management of Innovation*. London: Tavistock Publications.

Carayannis, E.G., Campbell, D.F. (2009). "Mode 3" and "Quadruple Helix": Toward a 21st Century Fractal Innovation Ecosystem, *International Journal of Technology Management*, 46(3–4), pp. 201–234. DOI: 10.1504/IJTM.2009.023374.

Cassiman, B., Veugelers, R. (2002). R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium, *American Economic Review*, 92(4), pp. 1169–1184. DOI: 10.1257/00028280260344704.

Chyba, Z., Kacprzak, J. (2019). Źródła pozyskiwania innowacji a strategie innowacyjne przedsiębiorstw, *Studia i Prace WNEiZ US*, 55, pp. 153–162. DOI: 10.18276/sip.2019.55-13.

Cillo, V., Rialti, R., Bertoldi, B., Ciampi, F. (2021). Dynamic Capabilities in Innovation Collaboration, *British Food Journal*, 121(2), pp. 242–258.

Cohen, W.M., Levinthal, D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly*, 35(1), pp. 128–152. DOI: 10.2307/2393553.

Criscuolo, P., Nicolaou, N., Salter, A. (2012). The Elixir (or Burden) of Youth? Exploring Differences in Innovation Between Start-ups and Established Firms, *Research Policy*, 41(2), pp. 319–333. DOI: 10.1016/j.respol.2011.12.001.

Czarnitzki, D., Hottenrott, H. (2011). R&D Investment and Financing Constraints of Small and Medium-Sized Firms, *Small Business Economics*, 36(1), pp. 65–83. DOI: 10.1007/s11187-009-9189-3.

De Loecker, J. (2013). Export Market Entry and Productivity, *Econometrica*, 81(6), pp. 2417–2471.

Dong, Y., Wei, Z., Liu, T., Xing, X. (2020). R&D Intensity and Innovation Performance, *Sustainability*, 13(1), pp. 328. DOI: 10.3390/su13010328.

Dosi, G. (1988). Sources, Procedures, and Microeconomic Effects of Innovation, *Journal of Economic Literature*, 26(3), pp. 1120–1171.

Etzkowitz, H., Leydesdorff, L. (1995). The Triple Helix – University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development, *EASST Review*, 14(1), pp. 14–19.

Eurostat (2021). *Community Innovation Survey – Microdata. Additional Information on Content of CIS Microdata (CIS 2018)*, https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey (accessed: 24.01.2026).

Evangelista, R., Vezzani, A. (2010). The Economic Impact of Technological and Organizational Innovations. A Firm-Level Analysis, *Research Policy*, 39(10), pp. 1253–1263. DOI: 10.1016/j.respol.2010.08.004.

Filho, D.V., O'Neale, D.R. (2020). The Role of Bipartite Structure in R&D Collaboration Networks, *Journal of Complex Networks*, 8(4), Article cnaa016. DOI: 10.1093/comnet/cnaa016.

Fleming, L. (2001). Recombinant Uncertainty in Technological Search, *Management Science*, 47(1), pp. 117–132. DOI: 10.1287/mnsc.47.1.117.10671.

Gnyawali, D.R., Srivastava, M.K. (2013). Complementary Effects of Clusters and Networks on Firm Innovation: A Conceptual Model, *Journal of Engineering and Technology Management*, 30(1), pp. 1–20. DOI: 10.1016/j.jengtecman.2012.11.001.

Griliches, Z. (1998). *R&D and Productivity. The Econometric Evidence*. Chicago: University of Chicago Press.

Grossman, G.M., Helpman, E. (1991). Trade, Knowledge Spillovers, and Growth, *European Economic Review*, 35(2–3), pp. 517–526. DOI: 10.1016/0014-2921(91)90153-A.

Hall, B.H., Mairesse, J., Mohnen, P. (2010). Measuring the Returns to R&D. In: *Handbook of the Economics of Innovation* (pp. 1033–1082), B.H. Hall, N. Rosenberg (Eds.). Amsterdam: Elsevier.

Hitt, M.A., Ireland, R.D., Hoskisson, R.E. (2007). *Strategic Management: Competitiveness and Globalization. Concepts and Cases* (7th ed.). Mason: Thomson South-Western.

Jasiński, A.H. (2021). *Współczesna scena innowacji. Wyzwania dla przedsiębiorców i menedżerów*. Warszawa: Poltext.

Jasiński, A.H. (2025). Innowacyjność przedsiębiorstw przemysłowych w latach 2015–2022. Mierniki i ocena w Polsce, *Gospodarka Narodowa. The Polish Journal of Economics*, 321(1), pp. 68–83. DOI: https://doi.org/10.33119/GN/194055.

Juergensen, J.J., Love, J.H., Surdu, I., Narula, R. (2024). Learning-by-Exporting: The Strategic Role of Organizational Innovation, *International Business Review*, 33(6), 102339. DOI: 10.1016/j.ibusrev.2024.102339.

Kamutando, G., Tregenna, F. (2024). Complementarity in Innovation, *Economics of Innovation and New Technology*, 33(6), pp. 792–818. DOI: 10.1257/0022051042177685.

Keller, W. (2004). International Technology Diffusion, *Journal of Economic Literature*, 42(3), pp. 752–782.

Laursen, K., Salter, A. (2006). Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms, *Strategic Management Journal*, 27(2), pp. 131–150. DOI:10.1002/smj.507.

Love, J.H., Roper, S. (2015). SME Innovation, Exporting and Growth: A Review of Existing Evidence, *International Small Business Journal*, 33(1), pp. 28–48. DOI: 10.1177/0266242614550190.

Maffei, H., Meredith, J.R. (1995). Infrastructure Innovation: The Role of Pilot Implementation in Technology Development and Diffusion, *Journal of Product Innovation Management*, 12(6), pp. 417–429. DOI: 10.1111/1540-5885.1260417.

Martínez-Ros, E., Labeaga, J. (2009). Product and Process Innovation: Persistence and Complementarities, *European Management Review*, 6(1), pp. 64–75. DOI: 10.1057/emr.2009.4.

Melitz, M.J., Redding, S.J. (2021). Trade and Innovation, *Annual Review of Economics*, 13, pp. 1–33.

Milgrom, P., Roberts, J. (1995). Complementarities and Fit Strategy, Structure, and Organizational Change in Manufacturing, *Journal of Accounting and Economics*, 19(2–3), pp. 179–208. DOI: 10.1016/0165-4101(94)00382-F.

Mińska-Struzik, E. (2014). *Od eksportu do innowacji. Uczenie się przez eksport polskich przedsiębiorstw*. Warszawa: Difin.

OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, *The Measurement of Scientific, Technological and Innovation Activities*. Paris: OECD Publishing. DOI: 10.1787/9789264239012-en.

Oksanych, O. (2019). Innowacyjność sektora MŚP w Polsce: problemy i perspektywy, *Nierówności Społeczne a Wzrost Gospodarczy*, 57(1), pp. 351–363. DOI: 10.15584/nsawg.2019.1.25.

Rhee, Y.W., Ross-Larson, B., Pursell, G. (1984). *Korea's Competitive Edge. Managing the Entry Into World Markets*. Baltimore–London: Johns Hopkins University Press.

Song, M., Kim, B. (2024). An Analysis of Critical Factors Affecting the Success of Open Innovation Strategies in High-Tech Firms: The Case of South Korea, *Administrative Sciences*, 14(11), p. 274. DOI: 10.3390/admsci14110274.

Statistics Poland (2020). *Podręcznik Oslo 2018: Zalecenia dotyczące pozyskiwania, prezentowania i wykorzystywania danych z zakresu innowacji. Pomiar działalności naukowo-technicznej i innowacyjnej* (4th ed.), https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/nauka-i-technika/podrecznik-oslo-2018,18,1.html (accessed: 09.04.2026).

Statistics Poland (2022). *Działalność badawcza i rozwojowa w Polsce w 2021 r*. Warszawa: Statistics Poland.

Statistics Poland (2025). *Zeszyt metodologiczny. Działalność innowacyjna przedsiębiorstw*, https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/nauka-i-technika/zeszyt-metodologiczny-dzialalnosc-innowacyjna-przedsiebiorstw,24,1.html (accessed: 09.04.2026).

Teece, D.J. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, *Research Policy*, 15(6), pp. 285–305. DOI: 10.1016/0048-7333(86)90027-2.

Teece, D.J., Pisano, G., Shuen, A. (1997). Dynamic Capabilities and Strategic Management, *Strategic Management Journal*, 18(7), pp. 509–533. DOI: 10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z.

Topkis, D.M. (1978). Minimizing a Submodular Function on a Lattice, *Operations Research*, 26(2), pp. 305–321.

Utterback, J.M. (1994). *Mastering the Dynamics of Innovation*. Boston: Harvard Business School Press.

Zhang, G., Wang, X., Duan, H. (2019). How Does the Collaboration With Dominant R&D Performers Impact New R&D Employees' Innovation Performance in Different Cultural Contexts? A Comparative Study of American and Chinese Large Firms, *Technological Forecasting and Social Change*, 148, 119728. DOI: 10.1016/j.techfore.2019.119728.

Chapter 10

The Evolution of Science and Innovation Policy in Poland

Marzenna Anna Weresa

10.1. Introduction

In today's knowledge-based economy, science and innovation policy largely determine a country's pace of development and competitive position. Their role is not limited to supporting scientific research, but also involves creating an environment conducive to the generation and implementation of innovation through access to appropriate instruments and strategies. Like other European countries, Poland has been gradually developing its approach to supporting research, technology and innovation, adapting it to the current economic challenges related to the digital and green transitions, as well as the need to enhance the resilience and competitiveness of the economy in the face of global change.

The aim of this chapter is to discuss the directions in which science and innovation policy in Poland has evolved since 2015, with particular emphasis on priorities extending to 2035, and to identify the key challenges and institutional factors that determine its implementation. The analysis comprises a theoretical part, focusing on the essence and basic assumptions of science and innovation policy, and an empirical part describing current trends in the development of these two policy dimensions in the European Union and in Poland. The study draws on the most recent strategic documents and on the results of a literature review based on scientific publications and national and international reports. The discussion concludes with findings concerning the key challenges and directions for the further development of science and innovation policy in Poland.

10.2. Theoretical foundations of science and innovation policy

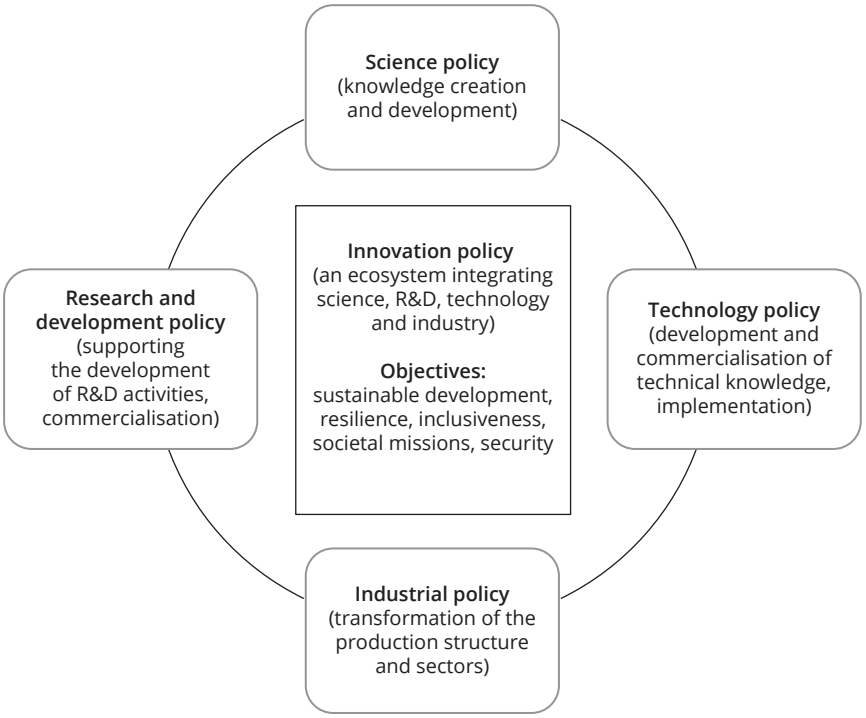
The contemporary approach to shaping science and innovation policy is based on a systemic perspective, in which the various areas of state intervention function as components of a single ecosystem for knowledge creation, technological development, and innovation [OECD, 2025]. This approach assumes the existence of interrelationships between different public policies – economic, educational, industrial, regional and social – which together create an environment conducive to the emergence and dissemination of innovation [Weresa, 2022]. The aim of policy understood in this way is not only to develop knowledge and technology, but also strengthen economic resilience, promote sustainable development, and enhance society's ability to adapt in response to technological changes and global crises [Paunov, Planes-Satorra, 2021]. Within a narrower perspective, however, four key areas can be distinguished, which relate to the research and development, science, technology and innovation spheres, as well as the specific policies that regulate their functioning, namely: research and development policy, science policy, technology policy, and industrial policy. These four dimensions of research and innovation development are closely interlinked within the framework of innovation policy (Figure 10.1).

Science policy is defined as the measures and actions undertaken by public authorities aimed at setting priorities, coordinating and supporting the development of science, and the education and training of scientific personnel. Technology policy, in turn, focuses on promoting technological development, application and diffusion, especially in strategic areas such as defence, energy and environmental protection [Dodgson, Bessant, 1996; Weresa, 2022]. Together, these two spheres form the concept of science and technology policy, which aims to support the development of science and technology and to disseminate scientific achievements in society.

The literature on the subject also distinguishes research and development (R&D) policy, which includes measures to support and coordinate scientific research and development activities. Its aim is to define research priorities and funding principles and, in a narrower sense, primarily support investment in research and development. It encompasses selected elements of science policy, and science and technology policy, focusing on creating conditions conducive to the development of knowledge and technology. Some scholars argue that R&D policy focuses primarily on the supply of research outputs – that is, on the process of knowledge creation and accumulation [Martin, 2016; Lenihan, Mulligan, Perez-Alaniz, Rammer, 2025] – as a mechanism to stimulate growth [Minniti, Venturini, 2017]. Today, this policy has an international

dimension: it is pursued both at the level of individual countries (e.g. through national research programmes) and within regional integration groupings, including the European Union (e.g. EU Framework Programmes).

Figure 10.1. Interconnections between policies supporting innovation: a systemic perspective



Source: own elaboration based on Weresa [2022, p. 88].

In recent years, industrial policy has gained particular importance, becoming a key component of science, technology and innovation strategies [OECD, 2025]. In this case, too, an ecosystem perspective is adopted, whereby industrial policy encompasses not only individual sectors but also related industries upstream and downstream along the value chain, as well as a diverse range of stakeholders.

Innovation policy, which combines elements of science, research and development, technology, and industrial policy, is closely linked to the three areas described above. In the broadest sense, innovation policy can be defined as a set of public policy measures designed to support the creation, implementation and dissemination of new solutions, including technological innovations [Jasiński, 2018]. Its aim is to enhance the economy's innovation capacity, support the transfer of knowledge and technology,

and address societal challenges through the implementation of so-called mission-oriented policies [Mazzucato, 2018; OECD, 2025]. The contemporary approach to innovation policy is also based on a systemic perspective, in which policy is viewed as part of a complex ecosystem encompassing science, the economy, society, and public administration. Consequently, it can be concluded that contemporary innovation policy brings together activities in the fields of science, technology and industry, thereby becoming an instrument for coordinating various public policies and responding to the key civilisational challenges of the twenty-first century. Within this framework, science, research and development, technology, and industrial policies function as interdependent components of the innovation policy ecosystem. By integrating these areas, it becomes possible to build a coherent system to support innovation, from the creation of knowledge to its implementation in the economy and society.

The evolution of how innovation is perceived – from the linear model, in which research and development is regarded as the starting point, to the systemic approach, where innovation is understood as the result of complex interactions between individuals, institutions and the broader environment (see Chapter 1) – demonstrates that innovation policy requires moving beyond one-dimensional interpretative frameworks. As the systemic approach developed, different analytical perspectives – national, regional, sectoral and technological – began to be combined. The integration of these perspectives led to the development of the concept of an innovation policy mix. Its essence lies in constructing a set of public tools that, within the framework of an innovation system, operate as effectively as possible, complement one another, and create a synergy effect. Consequently, innovation policy instruments are not selected in isolation, but rather in combination with each other, taking into account their ability to influence different stages of the innovation process. In practice, this involves combining solutions from different areas of state activity (e.g. fiscal tools with science or education policy mechanisms) and directing them towards addressing specific development challenges. As a result, innovation policy design is carried out through the lens of the challenges specific to this field, which may vary in nature depending on the technological advancement and level of development of a country or region. Compared with highly developed economies, developing countries operate within a technological gap that limits their ability to create their own innovations and increases their dependence on technology transfer. This situation requires changes in the funding of R&D activities and the implementation of institutional solutions that effectively support innovation and accelerate economic development [Ciborowski, 2019]. By contrast, countries located on the so-called technological frontier, whose development is no longer based on imitation but on the creation and commercialisation of new technologies that set global innovation trends, require different types of policy instruments. Consequently,

a challenge-oriented approach requires a systemic, holistic view of innovation policy, encompassing the interdependencies between regulations, institutional structures, and factors shaping the economy's ability to generate and absorb innovations. This implies the need to integrate activities across multiple areas and to coordinate the different dimensions of public policy affecting the innovation ecosystem, as emphasised, *inter alia*, by Borrás and Edquist [2019]. Based on this approach, a new type of innovation policy has emerged – the so-called transformative innovation policy – which goes beyond the traditional framework of supporting research and development or improving technologies within existing systems. The focus here is not merely on a quantitative increase in innovation, but rather on the transformation of entire social and technological systems through creating strong links between technology, users, institutions, regulations and culture, and the active support of innovation aimed at addressing major social, environmental and economic challenges, such as climate change, social inequalities, or the transformation of food, energy or transport systems [Fagerberg, 2018; Lundvall, 2023]. The main elements distinguishing transformative innovation policy from traditional innovation policy models are:

- a systemic approach – reflecting the fact that problems have multiple dimensions (technological, social, and institutional) and therefore require the cooperation of multiple stakeholders;
- co-creation and inclusiveness – innovation policy understood in this way engages entrepreneurs, researchers, civil society, users and representatives of various levels of public administration;
- experimentation and learning – transformation is regarded as a complex and unpredictable process, which creates the need for experimentation, monitoring and learning from mistakes;
- value orientation – innovation policy is assumed to promote specific values (e.g. fairness and sustainability) and to influence the balance of power and the way systems function [Ghosh, Velasco, Chakraborty, Mguni, Lestari Yuana, 2025].

In this way, transformative innovation policy combines innovation with social and environmental missions and supports more equitable and more sustainable transformations than policies focused solely on economic growth. It enables countries and regions to create frameworks for shaping transformation pathways (e.g. transitions from fossil fuel-based economies to low-carbon economies) by supporting innovation, regulatory changes, and the development of new business models. This approach is increasingly regarded as essential in the face of global challenges such as climate change, environmental degradation, and socio-economic inequalities, where traditional innovation policies – particularly those focused solely on supporting R&D activities – may prove insufficient.

10.3. Science and innovation policy in Poland: Regulatory framework and directions for development

In Poland, science and innovation policy is governed by separate, although partially overlapping, strategic documents. Science policy focuses on the development of scientific research, human capital, and research infrastructures, whereas innovation policy is oriented towards the application of knowledge and technology in economic processes. A common area of both policies is the promotion of knowledge transfer and the commercialisation of research results, as well as the strengthening of cooperation between the scientific and business communities.

In recent years, the direction of science policy has been shaped by horizontal programmes aimed at strengthening the role of science in addressing the challenges of the country's social and economic development (e.g. improving the quality of life, developing public health, education or technological security). Another key element of science policy is the development of the research funding system and support for programmes promoting scientific excellence and international cooperation, with the aim of enhancing the competitiveness of Polish science. Programmes implemented by the National Science Centre (NCN), the National Centre for Research and Development (NCBR) and the National Agency for Academic Exchange (NAWA) contribute significantly to this goal.

One example of an instrument in which science policy assumes a form clearly oriented towards societal needs and practical application is the programme entitled *Science for the Development of Society*, launched by the Minister of Science and Higher Education [Ministry of Science and Higher Education, 2025]. The programme is designed to provide support to entities operating within the higher education and research system, as well as to other organisations engaged in promoting science, in the following areas: conducting research with application potential, developing cooperation with the socio-economic environment, and implementing solutions that benefit the national, regional, and local communities. The programme provides funding for research projects in four key areas:

a) new horizons in science, which focuses on frontier research and the development of methods for implementing research results;
b) science for innovation, supporting the strengthening of cooperation between the scientific community and the socio-economic environment, as well as the implementation of research and development outcomes;

c) physical education for an active and healthy society, including, *inter alia*, the promotion of physical activity, sport in universities, and activities for people with disabilities;
d) social medicine, focused on the prevention of lifestyle diseases, the development of biomedical technologies and the promotion of healthy lifestyles.

Entities eligible to participate in the programme include universities, institutes of the Polish Academy of Sciences, research institutes, and members of the Łukasiewicz Research Network. The programme is oriented towards the development of science understood as a public good, and participating entities are required to collaborate with partners from the socio-economic environment and to demonstrate the implementation potential for their research results.

In line with international trends, the science policy model reflected in the programme combines the traditional functions of the research system with the logic of mission-oriented innovation policy and responsible research and innovation. In this approach, research funding is aligned with an interdisciplinary pursuit of public objectives aimed at improving the quality of life and well-being of society. Consequently, the programme exemplifies the convergence of science and innovation policy in Poland, where the cognitive function of science is linked to its ability to generate societal value.

The basic framework for contemporary innovation policy, in turn, is provided by the *Productivity Strategy 2030* (a document linked to the earlier *Strategy for Innovation and Economic Efficiency*). Within this framework, innovation is defined as a tool for achieving the overarching goal of progressive, sustainable and inclusive productivity growth based on knowledge and technology. The document places particular emphasis on increasing private investment and supporting the digital transformation of companies; developing skills and lifelong learning; promoting eco-innovation and the circular economy; improving the quality of public governance and cooperation in innovation ecosystems; and increasing the intensity of knowledge and technology utilisation in the economy [Ministry of Economic Development and Technology, 2022].

This innovation policy framework assumes the combination of tax, regulatory, research and development, educational and infrastructure instruments in such a way that they reinforce rather than exclude one another, thereby creating a policy mix.

The strategic document integrating the scientific and innovation perspectives is Poland's Development Strategy 2035, which sets out the overarching framework for the country's medium-term development policy, and public consultations and discussions on the final form of the Strategy are currently underway. Its main message is the pursuit of objectives that go beyond economic growth and include ensuring a high quality of life for all citizens, regardless of their place of residence. The three principal objectives of the Strategy are:

a) economic competitiveness – understood as Poland's ability to maintain long-term economic growth;
b) social and territorial cohesion – aimed at ensuring continuous improvements in the quality of life;
c) national security, understood broadly – encompassing the resilience of the state, institutions and society to crises.

A new component of industrial and innovation policy is the national security pillar, which in this context is perceived as a driving force for technological development, industrial modernisation, and innovation. This reflects the link between efforts to modernise the Polish economy and the development of the country's defence capabilities, which, in turn, is consistent with a broader trend in industrial and innovation policies across the NATO alliance and the EU [Richardson et al., 2025].

A key area of intervention is the expansion and modernisation of the national defence industry base, aimed at reducing dependence on external suppliers, ensuring the continuity of defence capabilities in crisis situations, and increasing the share of domestically produced high-tech weapon systems. This is also intended to strengthen Poland's position within European and transatlantic value chains. Particular emphasis is placed on the development of a dual-use innovation ecosystem encompassing research and technologies in areas such as materials engineering, artificial intelligence, robotics, unmanned systems, satellite technologies, energy storage, and secure data processing. An additional element is provided by instruments to support R&D activities, including public research funding, technology-transfer platforms, incubators, and preferential treatment in public procurement. These measures are intended to promote the application of research results in both the civil and defence sectors. The strategy also prioritises the development of secure and resilient supply chains for key components, electronics, and advanced manufacturing technologies, in line with NATO and EU efforts to strengthen the manufacturing capabilities of the defence sector. These initiatives are complemented by the development of human capital, including education and the enhancement of competences in the fields of engineering and advanced manufacturing, cybersecurity and cryptography, satellite technologies, as well as artificial intelligence and autonomous systems, which is a prerequisite for the creation of a competitive and resilient industrial and innovation ecosystem.

Based on analyses by the World Bank, another area can be identified in which Poland's research and innovation capabilities are a key condition for development. This area concerns the development of green technological capabilities, as well as the creation of new competitive advantages in the fields of decarbonisation and sustainable development [Ambasz, Sanchez-Reaza, Zuniga, 2023]. Poland's research and innovation system possesses growing potential, but its utilisation in the field of

green transformation remains limited. Expenditure on R&D in renewable energy and environmental protection, as well as patent activity in green technologies, remains insufficient, while collaboration between academia and business, together with the level of internationalisation of research, remain weak. A key challenge is to strengthen human capital and develop skills in the field of science and technology, while also strengthening mechanisms to support the uptake and implementation of green technologies, particularly within the small and medium-sized enterprise sector. There is also a lack of coordination between public instruments and a coherent strategy for financing green innovation, which justifies calls for the creation of an integrated funding mechanism – a so-called green innovation fund – that would combine funding for basic and applied research with instruments to support commercialisation [Ambasz et al., 2023].

In summary, the objectives of contemporary innovation policy in Poland highlight the growing importance of national security, particularly with regard to the development of dual-use technologies and the strengthening of the national defence industrial base. At the same time, the climate transition requires an increase in green innovation capacity and a more effective link between research and sustainable development, which means that the future competitiveness of the economy will depend on the effective integration of defence and environmental priorities within a single, coherent science and innovation policy.

10.4. Conclusions

In recent years, science and innovation policies in Poland have undergone a significant evolution, from a linear approach focused primarily on research and commercialisation to a systemic and transformative perspective. The integration of science and innovation activities is becoming crucial in the context of responding to demographic, climate-related, technological, and geopolitical challenges. Within the regulatory framework currently in force in Poland, science policy supports the capacity to generate knowledge, while innovation policy enables its diffusion and utilisation within the economy. These two dimensions overlap, thereby contributing to the development of a competitive and resilient economy capable of operating under global megatrends such as digitalisation, artificial intelligence, decarbonisation, and the shortening of supply chains.

Currently, national security is gaining prominence in Poland's innovation policy, particularly with regard to the development of dual-use technologies and the establishment of a resilient defence industrial base. At the same time, the climate transition requires strengthening technological capabilities in the field of green innovation,

improving the quality of cooperation between science and business, and aligning research more closely with the needs of sustainable development. The combination of these two perspectives suggests that the country's resilience and the competitiveness of its economy will increasingly depend on its ability to integrate the security agenda with a strategically targeted innovation policy encompassing both defence-related and environmental technologies.

Based on the analysis of strategic documents, a set of horizontal priorities necessary for the integration of science and innovation policy can be identified, including:

- stronger integration of science, research and development, and innovation policies around the achievement of the Sustainable Development Goals;
- increasing funding for science, R&D and education, with particular emphasis on addressing the challenges associated with the digital and green transitions, including the development of eco-innovation and environmental technologies;
- supporting open innovation and international cooperation in science and innovation activities, in particular through EU programmes (e.g. Horizon Europe, EIT) and other international initiatives;
- expanding innovation-supporting infrastructure, including technology parks, laboratories, and competence centres;
- reforming the education system to foster a culture of innovation, including entrepreneurial skills, risk acceptance, and trust-based relations between academia, business and public administration;
- implementing evidence- and data-driven policy solutions supported by the foresight method, which requires the development of analytics, open data and new mechanisms for evaluating the effectiveness of public policy instruments.

References

Ambasz, D., Sanchez-Reaza, J., Zuniga, P. (2023). *Institutions in Fostering Green Innovation in Poland*, http://documents.worldbank.org/curated/en/099050323054520864 (accessed: 29.10.2025).

Borrás, S., Edquist, C. (2019). *Holistic Innovation Policy. Theoretical Foundations, Policy Problems, and Instrument Choices*. Oxford: Oxford University Press. DOI: 10.1093/oso/9780198809807.001.0001.

Ciborowski, R. (2019). The Schumpeterian Approach to Technological Changes in Different Economic Systems, *Eastern European Journal of Transnational Relations*, 3 (1), pp. 95–104. DOI: 10.15290/eejtr.2019.03.01.07.

Dodgson, M., Bessant, J. (1996). *Effective Innovation Policy: A New Approach*. London: International Thomson.

Fagerberg, J. (2018). Mobilizing Innovation for Sustainability Transitions: A Comment on Transformative Innovation Policy, *Research Policy*, 47(9), pp. 1568–1576. DOI: 10.1016/j.respol.2018.08.012.

Ghosh, B., Velasco, D., Chakraborty, K., Mguni, P., Lestari Yuana, S. (2025). Transformative Innovation Policy: An Analytical Review of Key Methods and Challenges, *Annual Review of Environment and Resources*, 50, pp. 593–623. DOI: 10.1146/annurev-environ-111523-102251.

Jasiński, A.H. (2018). Polityka innowacyjna w procesie transformacji w Polsce: czy skuteczna?, *Optimum Economic Studies*, 3(93), pp. 221–239. DOI: 10.15290/oes.2018.03.93.18.

Jasiński, A.H. (2021). Czy mamy stagnację innowacji w polskim przemyśle?, *Gospodarka Narodowa. The Polish Journal of Economics*, 1(305), pp. 111–134. DOI: 10.33119/GN/132484.

Lenihan, H., Mulligan, K., Perez-Alaniz, M., Rammer, Ch. (2025). R&D Policy Instrument Mix Sequencing: Evaluating the Impact of Receiving R&D Grants and R&D Tax Credits Over Time on Firm-Level R&D, *Industry and Innovation*, 32(5), pp. 540–573. DOI: 10.1080/13662716.2024.2388650.

Lundvall, B.Å. (2023). Transformative Innovation Policy – Lessons from the Innovation System Literature, *Innovation and Development*, 14(2), pp. 297–314. DOI: 10.1080/2157930X.2022.2158996.

Martin, B.R. (2016). R&D Policy Instruments – A Critical Review of What We Do and Don't Know, *Industry and Innovation*, 23(2), pp. 1–20. DOI: 10.1080/13662716.2016.1146125.

Mazzucato, M. (2018). Mission-Oriented Innovation Policies: Challenges and Opportunities, *Industrial and Corporate Change*, 27(5), pp. 803–815. DOI: 10.1093/icc/dty034.

Ministry of Economic Development and Technology (2022). *Strategia Produktywności 2030*, https://www.gov.pl/web/rozwoj-technologia/strategia-produktywnosci-2031 (accessed: 28.10.2025).

Ministry of Science and Higher Education (2025). *Nauka dla Rozwoju Społeczeństwa*, https://www.gov.pl/web/nauka/nauka-dla-rozwoju-spoleczenstwa (accessed: 17.11.2025).

Minniti, A., Venturini, F. (2017). The Long-Run Growth Effects of R&D Policy, *Research Policy*, 46(1), s. 316–326. DOI: 10.1016/j.respol.2016.11.006.

OECD (2025). *Measuring Science and Innovation for Sustainable Growth*. Paris: OECD Publishing. DOI: 10.1787/3b96cf8c-en.

Paunov, C., Planes-Satorra, S. (2021). Science, Technology and Innovation in the Time of COVID-19, *OECD Science, Technology and Industry Policy Papers*, 99. DOI: 10.1787/234a00e5-en.

Richardson, K., Renda, A., Schwaag Serger, S., Walz, R., Potočnik, D., Świeboda, P., Christophilopoulos, E., Balland, P.A., Grabbe, H., Muntean, B., Castaño Marín, M.L., Weresa, M., Alkemade, F., Dunlop, K., Simonsson, J. (2025). *Making the Most of EU Research and Innovation Investments – Rethinking Dual Use*. Luxembourg: European Commission, Directorate-General for Research and Innovation, Publications Office of the European Union. DOI: 10.2777/6637451.

Weresa, M.A. (2022). *Polityka innowacyjna. Nowe tendencje w teorii i praktyce*. Warszawa: Wydawnictwo Naukowe PWN.

Conclusions

Marzenna Anna Weresa, Arkadiusz Michał Kowalski

The analyses presented in this monograph confirm that R&D constitutes one of the key – and at the same time highly complex – pillars of the competitiveness of modern economies. From the perspective of endogenous growth theory and knowledge-based approaches, R&D plays a dual role: on the one hand, it serves as a mechanism for accumulating knowledge capital and as a source of technological, organisational and digital innovation; on the other hand, it represents an important determinant of resilience and long-term competitiveness in the face of intensifying geopolitical, climate-related, and demographic shocks. However, the findings presented in Chapters 1–10 demonstrate that the relationship between R&D expenditure and competitiveness is neither straightforward nor automatic, and depends on the quality of institutions, the structure of the R&D sector, complementarity with other resources, the degree to which R&D is embedded in the national innovation ecosystem, and international links among science, R&D and business.

In terms of its competitive position, Poland remains an economy that is still catching up with the most technologically advanced countries of the European Union, while gradually – albeit rather slowly – strengthening its presence in more demanding market segments. This is reflected in income convergence with the more developed economies of Western Europe and the positive contribution of total factor productivity (TFP) to economic growth. These developments indicate a gradual strengthening of the economy's capacity to improve the efficiency with which production factors are utilised, although it should be noted that this process remains highly sensitive to external shocks, including the financial crisis, the pandemic, the war in Ukraine, and the energy crisis. In this context, the results of R&D activities and the effects of innovation can serve not only as a source of technological advantages, but also as a buffer against disruptions and as a factor supporting the process of economic convergence.

An analysis of exports revealed a slow but noticeable shift towards specialisation in more technology-intensive products, particularly in the fields of electronics and electrical goods, although the share of high-tech goods in exports remains lower than the EU average.

Analyses of the relationship between foreign direct investment (FDI) and R&D show that the positive impact of FDI inflow on R&D expenditure expected in economic growth

theories is neither strong nor evident. Although foreign investors play a significant role in financing R&D, the results of econometric modelling of this relationship indicate that the mere presence of foreign capital has a limited impact on increasing R&D expenditure in the business sector. This confirms the findings from the literature, according to which the ability of foreign direct investment (FDI) to exert a meaningful impact on the national innovation system depends on a sufficiently high capacity of the host economy to absorb knowledge and technology, as well as deliberately targeted investments to strengthen this capacity. In practice, this means that the inflow of foreign investment more often reflects the attractiveness of the domestic R&D environment and serves to attract technology partners, rather than automatically generating an increase in domestic R&D activity.

In this context, Poland's experience after two decades of EU membership, in terms of developing its national R&D capacity and cooperating within the European Research Area, demonstrates that despite some progress, significant structural constraints still exist in this area. Positive signs of these processes include a more than twofold increase in the number of employees in the R&D sector in absolute terms and the growing role of the private sector in research funding. The share of R&D expenditure in GDP is also steadily increasing, despite remaining below the EU average. Progress in this area has been driven by both national support instruments and EU structural funds, although this does not alter the fact that innovation performance remains mixed, with the number of scientific publications increasing while the commercialisation of knowledge remains limited, patents are concentrated in the academic sector, and links between science and business remain relatively weak. However, the rapidly expanding startup ecosystem suggests the emergence of a new culture of innovation. Harnessing this potential requires further increases in R&D expenditure (ultimately reaching 3% of GDP), the strengthening of education – particularly in science, technology and engineering disciplines – the development of technology transfer and intellectual property protection mechanisms, and the consistent shaping of a pro-development regulatory environment, so that Poland can move from a catching-up economy to one that is driven predominantly by knowledge and innovation.

At the same time, analyses of innovation rankings indicate that Poland remains trapped within the category of "moderate innovators". While it is capable of transforming limited resources into results (innovation outputs), the input side – including the level of funding, the quality of institutions, the strength of links between science and business, and the role of SMEs – remains underdeveloped. Regional disparities in R&D expenditure and innovation potential further reinforce the dual nature of the system: on the one hand, there are metropolitan hubs of knowledge and innovation, while on the other, there are areas with low research intensity and limited capacity to absorb

technology. This means that public policy should simultaneously strengthen existing centres of technological excellence and create accelerated development pathways for peripheral regions.

Research on the innovativeness of small and medium-sized enterprises indicates the coexistence of two complementary pathways: an internal model based on intensive investment in R&D activities and technology absorption, and a network model in which international links, access to public funding, and knowledge transfer within capital groups and cooperation networks are of key importance. The findings presented in this monograph suggest that innovation policy needs to be more strongly diversified, as different instruments prove effective for companies operating in local markets and for exporters operating in global value chains. However, the common denominator remains the need to strengthen the absorptive capacity of enterprises, in particular through the development of technical competencies, more effective use of research results, and the establishment of stable, long-term links between business and the science system.

Another key finding emerging from the research presented in this monograph is the increasing complexity of the environment in which science and innovation policy are shaped. Poland is moving away from a linear understanding of R&D activities – as a sequence of research, development and commercialisation – in favour of a systemic and transformative approach, in which the key factor is the ability of the entire ecosystem to respond to megatrends such as digitalisation, decarbonisation, the shortening of supply chains, and escalating geopolitical risk. The objectives of innovation policy clearly indicate the growing importance of national security, particularly in the area of dual-use technologies and the development of a resilient defence industrial base, while also incorporating the green transformation and sustainable development agenda. This means that Poland's long-term competitiveness will depend on its ability to integrate science, innovation, industrial and security policies within a coherent policy mix focused on objectives that go beyond economic growth, in particular improving the quality of life of the population.

On this basis, several strategic recommendations for economic policy can be formulated. Firstly, it is necessary to further increase and stabilise expenditure on R&D and education – particularly in the fields of science and engineering – while shifting the focus of funding towards research and innovation addressing the challenges posed by the digital and climate transitions. Secondly, it is crucial to strengthen the systemic nature of policy, including the development of innovation infrastructure, technology transfer mechanisms, intermediary institutions, and open forms of international cooperation (e.g. through EU programmes). Thirdly, it is essential to implement a consistent reform of the institutional environment by simplifying procedures for

research and business, strengthening intellectual property protection, and promoting a culture of innovation based on trust, risk tolerance and the co-creation of solutions by the scientific community, the business sector, public administration, and civil society. Fourthly, sectoral and regional policies should be more closely coordinated with science and innovation policy in order to facilitate the diffusion of knowledge and technology across a broader group of enterprises and regions.

This monograph does not cover all aspects of the complex relationship between R&D and economic competitiveness, but it does identify several key areas that could form the basis for further research. These include, *inter alia*, the long-term effects of new innovation policy instruments, the impact of the energy transition and national security on the structure of R&D activities, as well as the importance of microeconomic data enabling a deeper understanding of innovation processes at the level of enterprises and regions. The findings presented in this monograph confirm that Poland has taken a significant step towards becoming a knowledge-based economy, but maintaining and strengthening this trajectory of change requires a consistent implementation of integrated public policy and further development of knowledge concerning the mechanisms through which R&D activities translate into sustained economic competitiveness and resilience.

The debate on the competitiveness of economies, which has gained new momentum in recent years, is increasingly focused on the importance of knowledge, innovation and the ability to respond rapidly to changing global conditions. In the face of escalating geopolitical tensions, the acceleration of the green and digital transitions, growing regulatory pressure, and demographic challenges, factors that foster sustained productivity growth and enable the creation of stable, long-term competitive advantages are becoming particularly important. One of the most significant factors is research and development (R&D), which serves not only as a source of new technologies and innovations but also as the foundation of a knowledge-based economy.

The economic literature on endogenous growth models emphasises that investment in research and development, as well as in human capital, can be a major internal driver of economic growth, enabling countries not only to close the development gap but also to build their own unique competitive advantages. In this context, the question arises as to the extent to which the Polish economy is leveraging the potential of R&D, and whether R&D is genuinely becoming a pillar of the country's competitive advantage in European and global markets.

Therefore, the main objective of this monograph is to determine the competitive position of the Polish economy relative to other European Union countries, with particular emphasis on the importance of research and development in shaping Poland's competitiveness. From a theoretical perspective, the publication seeks to enhance our understanding of the relationship between R&D and innovation, on the one hand, and the competitiveness of economies, on the other, particularly in terms of endogenous growth. The aim of the empirical research presented here is, in turn, to identify and assess the impact of R&D on the performance of the Polish economy in terms of foreign trade, productivity, income convergence and innovation, while also diagnosing the institutional and structural factors that facilitate or limit the utilisation of the country's R&D potential.

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