

Research and Development, Innovation and Competitiveness in the Age of the Fourth Industrial Revolution

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Abstract: This study examines the relationships between research and development (R&D), innovation, and national economic competitiveness, with particular attention to Hungary's situation. The author reviews the conceptual frameworks of competitiveness and innovation (Schumpeter, Porter, Krugman, OECD, Lengyel), presents the forms in which innovation manifests, and then, based on the Hungarian Central Statistical Office's latest data for 2022–2025, assesses the evolution of domestic R&D expenditure and innovation activity. The study also addresses Hungary's position in international competitiveness and innovation rankings (European Innovation Scoreboard, IMD World Competitiveness Ranking), as well as the impact of the Fourth Industrial Revolution and the data-driven economy on R&D. The author concludes that the key to lasting competitiveness lies in building a knowledge-based society and in the systematic, long-term support of corporate and state R&D&I activity.

Keywords: research and development, innovation, competitiveness, Fourth Industrial Revolution, knowledge-based economy

1 Introduction

Research and development (R&D) is an important priority in national economic strategy. In 2025 – according to preliminary data – Hungary spent 1.33% of GDP, a total of HUF 1,154 billion, on R&D activity, 8.0% more at current prices than in 2024; the share of the employed population engaged in R&D activity reached 1.14% [14]. R&D expenditure as a share of GDP has persistently exceeded 1% since 2009, reaching its peak to date in 2020 (1.61%), followed by a moderate decline and subsequent stagnation [12].

Competitiveness, research and development, and innovation are closely interlinked. Innovation also held a prominent place among the European Union's strategic priorities valid until 2020 (Europe 2020): smart growth aimed at building an economy based on knowledge and innovation, sustainable growth aimed at a more resource-efficient and competitive economy, and inclusive growth aimed at high

employment and social cohesion. This earlier strategy has now been superseded by the European Innovation Strategy (2022) and the objectives of the Digital Decade 2030 [7], which continue to place knowledge-based, innovation-driven and sustainable growth at their centre.

The theoretical foundations of innovation were first laid down by Schumpeter [26]. Competitiveness was originally a microeconomic concept; Porter and Krugman consider its examination at the national economic level meaningless [25, 10]. Nevertheless, the OECD has defined the concept as “the degree to which a country can, under free market conditions, produce goods and services that meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term” [22]. More recently, the OECD has also formulated a unified definition of competitiveness: “the ability of companies, industries, regions, nations and supranational regions to generate, while being exposed to international competition, relatively high income and employment levels on a sustainable basis” [16].

Today's competitiveness-enhancing trends place the main emphasis on knowledge, innovation and human resource development, which necessitates the continuous rethinking of measurement methods [17]. Rather than the earlier approach based on the spatial reallocation of resources, post-modern regional policy seeks to activate internal resources — regional, social, organisational, cultural, environmental and economic factors — and to explore new opportunities; it envisages development through the acquisition of information, the extension of knowledge and innovation, and the building of relational networks [17].

Entering the era of the Fourth Industrial Revolution, the pace of innovation, technological development and data generation is faster than ever before, posing new challenges for both corporate and state R&D policy.

2 Research and Development and Innovation: Conceptual Frameworks

Research and development and innovation form the basis of competitiveness. Competitiveness has been addressed in the work of numerous authors [15, 2, 3], who agree that no universally accepted definition or uniform method of measurement exists to this day [20, 21].

The OECD distinguishes between micro-, macro- (national economic) and structural competitiveness; structural factors are linked to the firm, such as infrastructure, services, and the characteristics of innovation and R&D&I [22]. According to Török, “at the micro level, the concept of competitiveness means the ability to gain a position and hold one's own in market competition among

individual firms and competitors, while at the macroeconomic level it refers to competition among national economies” [28]. Competitiveness, therefore, does not merely denote market success but also encompasses the capacity for successful adaptation.

Analyses show that it is not only the competitiveness of the business sector that determines a country's competitiveness, but also the innovativeness of the non-business sector and society as a whole [19]. Innovation capacity and opportunities are shaped by asset elements that were previously little valued and difficult to quantify, intangible yet decisive — trust, knowledge, relational capital, and willingness to cooperate [18].

Innovation manifests itself in the following forms:

1. Product development – new products and services that either create new demand or satisfy existing demand.
2. Technological development – the introduction of new technology, or the establishment or development of a production process.
3. Organisational development – internal organisational transformation brought about by changing circumstances or mergers.
4. Market innovation – entry into a new market.

According to a widely used definition, innovation is “the transformation of an idea into a new or improved product introduced onto the market, or into a new or improved process used in industry or commerce, or into a new approach to a social service” [22]. Schumpeter divides the innovation process into three phases: invention (the emergence and development of new ideas), innovation (turning ideas into marketable products/production processes), and diffusion (the spread of new products and processes as they conquer markets); together, these ultimately generate revenue [26].

3 Innovation Activity among Domestic Enterprises

In accordance with the methodological requirements of the European Union's Community Innovation Survey, the Hungarian Central Statistical Office (KSH) surveys the innovation-related data of enterprises employing at least 10 people

every two years.² The scope and methodology of the data collection have been revised several times over the years.³⁴

According to the most recent survey, covering the 2022–2024 period, 36% of the enterprises observed carried out some form of innovation activity, 5.7 percentage points higher than the share recorded for 2020–2022 [13]. The improvement is primarily attributable to the growing share of enterprises introducing business process innovation, and, in terms of employment size, the innovation activity of medium-sized enterprises (50–249 employees) improved most markedly [13]. This represents significant progress compared with the 25.6% recorded for 2012–2014 [11], although, owing to methodological changes, the two periods can only be compared to a limited extent (Table 1).

Period	Share of enterprises carrying out innovation activity
2012–2014	25.6%
2020–2022 (derived value)	~30.3%
2022–2024	36.0%

Table 1

Trend in the share of enterprises carrying out innovation activity

Source: KSH, 2016; KSH, 2025, own compilation

According to the earlier 2012–2014 survey, a significant proportion of innovative enterprises carried out activities related to product or process innovation, and in many cases also achieved favourable environmental effects [11]. At the time, there was still a considerable difference by size: among enterprises employing more than 250 people, the share of innovative enterprises exceeded 55%, whereas among those with fewer than 50 employees it stood at around 22%, with innovation being particularly high in the pharmaceutical and petroleum-processing industries [11]. The most recent, 2022–2024 survey — as noted above — has already narrowed this size-related gap somewhat, since it was precisely the innovation activity of medium-sized enterprises that improved most over the last two cycles [13]; the most recent, detailed data on activities related to product and process innovation, as well as on environmental effects, are available in the KSH STADAT database.

² The KSH collects data in accordance with the methodological requirements of the European Union's Community Innovation Survey.

³ In 2012, the scope of the observed sectors was expanded to include film, video and television programme production, sound recording and music publishing, programming and broadcasting activities, scientific research and development, as well as advertising and market research.

⁴ Act LXXVI of 2014 on Scientific Research, Development and Innovation.

4 Hungary's International Competitiveness and Innovation Position

The long-term set of conditions affecting competitiveness has been analysed by numerous researchers [23, 1], which can be summarised as follows: predictable economic policy; a supportive state (quality institutions, quality legislation, stable administration of justice, etc.); a well-trained, adaptive, healthy workforce; flexible, developing enterprises capable of adapting to competition; an efficient financial sector providing financing; a stable, growth-supporting tax policy; and a skilled workforce receptive to innovation.

The European Commission's annual European Innovation Scoreboard (EIS) report classifies Member States' innovation performance into the groups of Innovation Leaders, Strong, Moderate and Emerging Innovators. According to the 2025 edition, Hungary — despite achieving a 16.2 percentage point improvement compared with 2018 — slipped from the Moderate Innovators group into the Emerging Innovators group, as other countries improved relatively faster [5]. According to the 2026 edition, however, Hungary returned to the Moderate Innovators group [6]. This shift clearly illustrates that relative position depends at least as much on the performance of other Member States as on Hungary's own absolute progress.

Török distinguishes three approaches to macro-level competitiveness analysis: in the supply-side and demand-side approaches, the main determinants of competitiveness are the cost factors of external economic performance and the value of performance itself, while according to a third approach, competitiveness is an overall indicator of the state of the economy [29]. It is this third view that is represented by the institutes that annually publish countries' competitiveness rankings.

The World Economic Forum's previously frequently cited Global Competitiveness Index was suspended by the organisation in 2020, citing the coronavirus pandemic, and it has not published a regular, ranking-based competitiveness report since [30]. Analyses now rely more on the Switzerland-based IMD World Competitiveness Center's annual World Competitiveness Ranking publication. In the 2025 ranking, Hungary improved by six places compared with the previous year, and finished ahead of its regional competitors — Romania, Poland, Croatia, Bulgaria and Slovakia — owing primarily to its performance in the infrastructure and economic performance sub-factors [9].

As shown in Section 1, Hungary's GDP-proportionate R&D expenditure reached its peak to date in 2020 (1.61%), after which it gradually declined (Figure 1). This declining trend continues to lag significantly behind the EU average: in 2020, according to preliminary data, the EU27 average was 2.32%, exceeding 3% in the

traditionally R&D-intensive Member States (Belgium, Sweden, Austria, Germany, Denmark), while in Romania, the lowest, it did not even reach half a percent [12].

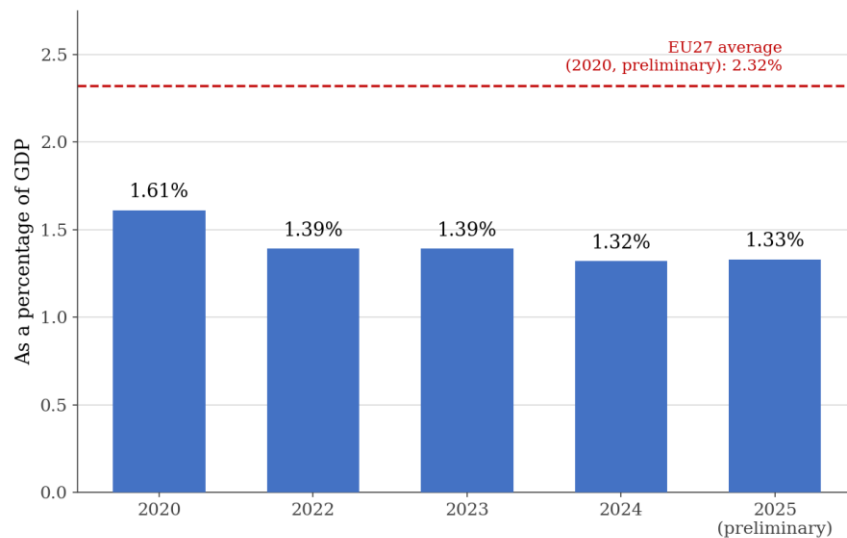


Figure 1

Trend in domestic R&D expenditure as a percentage of GDP, 2020–2025

Source: KSH, 2024; KSH, 2026, own compilation

Figure 1 clearly illustrates that, following the 2020 peak (1.61%) — also distorted by the pandemic — the indicator fell to 1.39% in 2022–2023, then to 1.32% in 2024, and the 2025 preliminary figure (1.33%) shows only a minimal improvement. Compared with the EU average shown in the figure (2.32%), Hungary's shortfall has therefore not narrowed; indeed, the domestic indicator has moved further away from its peak value since 2020, while — as shown earlier in this section — innovation activity (the share of enterprises engaging in innovation) improved over the same period. This suggests that the level of R&D expenditure and the trend in innovation activity do not necessarily move together, and that a decline in GDP-proportionate expenditure does not necessarily imply a decline in innovation performance.

5 The Fourth Industrial Revolution and the Data-Driven Economy

The successive waves of industrial revolution have brought about ever faster change: the first primarily transformed industrial labour, the second brought mass

production, and the third brought technological automation, programmability and telecommunications. The Fourth Industrial Revolution now under way surpasses these, bringing breakthroughs in cyberspace, information technology, robotics and numerous other fields.

The global volume of data is growing exponentially: while the world's digital datasphere stood at 33 zettabytes in 2018, estimates suggest it grew to 175–181 zettabytes by 2025 — more than a fivefold increase in just seven years [8]. The continuous growth in the number of internet-connected devices (IoT) and the volume of data they generate is further accelerating the spread of data-driven innovation and artificial intelligence, thereby also transforming the framework of R&D activity. According to Perez, the qualitative engine of economic development is innovation, which can contribute significantly to growth [24], particularly for small and medium-sized enterprises, which provide a substantial share of employment.

Rapid change in the information environment brings both advantages and disadvantages. Among the advantages is the fact that decision-makers are not left behind on relevant developments, and that ample data is available for mathematical and statistical analysis from which conclusions can be drawn. Among the disadvantages, however, is precisely the uncertainty created by the rapidly changing environment: the sheer volume of available data does not in itself guarantee sound decisions if the organisation lacks the methodological and human resources needed to process and interpret it. This reinforces the view that, alongside technological development, at least as much emphasis must be placed on the human factor and its training, so that organisations can make well-founded decisions that also take moral considerations into account [31].

6 The Corporate Environment of Innovation and Future Factors of Competitiveness

The most widely applied innovation framework today is the open innovation model, which is based on the integrated management of technologies and knowledge sources both within and outside the firm [4] (Figure 2).

THE OPEN INNOVATION CHANNEL

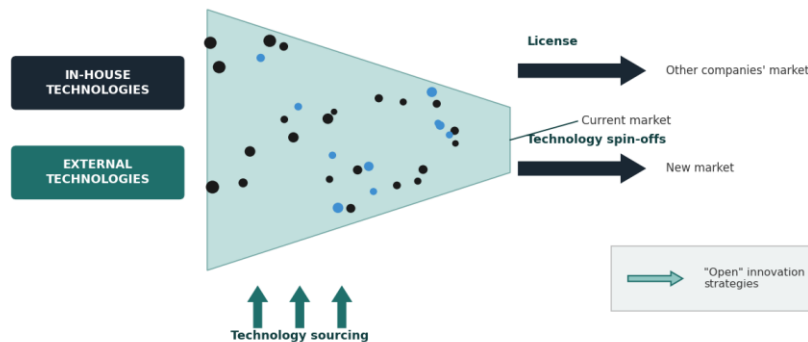


Figure 2

The open innovation model

Source: Döry, 2012

Figure 2 clearly illustrates the essence of open innovation: the firm does not rely solely on its own internally developed technologies but deliberately draws external technologies into its development channel, and then exploits the resulting innovations in several directions — licensing them to other companies, creating technological spin-off firms to target new markets, or introducing them in its current market. This model stands in sharp contrast to the traditional, closed innovation logic, according to which a firm must realise every idea, development and market launch using only its own internal resources, within its own walls. The importance of open innovation lies precisely in the fact that it reduces individual firms' development risk and time: externally sourced technology can accelerate market entry, while licensing and spin-off channels generate revenue even from innovations that would not fit the firm's own core business. However, since every firm — and the cultural and economic environment surrounding it — is unique, no single, universally applicable innovation model can be established; the extent and form of open innovation can vary considerably by industry, and even by firm.

The corporate innovation environment is shaped by several factors. Changes in consumer demand and purchasing power force innovative firms into continuous adaptation. The pace of competitors' innovation is likewise decisive: the risks of excessively accelerated product development cycles are well illustrated by Samsung's complete recall of the Galaxy Note 7 in 2016 for safety reasons, a reminder that shortening the time devoted to prototype testing and user feedback can pose serious reputational and financial risks. The role and extent of state support vary from country to country, while cooperation among firms is often hindered by

distrust related to the protection of intellectual property, particularly in the large-enterprise sector; micro- and small enterprises tend to be more of an exception in this respect. Responsible management of natural resources and environmental awareness can now, in themselves, constitute a market advantage. Finally, the pace of corporate growth has also accelerated: some companies are now taken public within 2–3 years, raising the question of whether this pace risks diluting the pool of stable companies with unstable players.

Patent activity remains an important indicator of competitiveness; in this respect, the United States, China, South Korea and Japan are the most active centres of innovation [32]. The innovation environment also depends heavily on cultural space: firms operating in the same industry and at the same technological level can differ considerably in their propensity for innovation and risk-taking, depending on how open the surrounding economic and social environment is to innovation and how tolerant it is of failure — this is one of the reasons why, even under the same EU regulatory framework, persistent differences in innovation performance remain among Member States.

Summary

The analyses clearly show that research and development and innovation are, and will remain, the driving forces of the economy, both now and in the future. In this context, building a knowledge-based society is one of the most important strategic goals. Hungary's R&D expenditure and innovation activity have improved considerably over the past decade, yet domestic indicators continue to lag behind the EU average and the leading innovator countries. It is not always advisable to compete on the basis of a large mass of human labour; for Europe — and for Hungary within it — it is primarily the development of knowledge and innovative thinking that can lay the foundations for lasting competitiveness.

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