

# R&D Performance Trends in Turkiye

Emerging  
Trends *in*  

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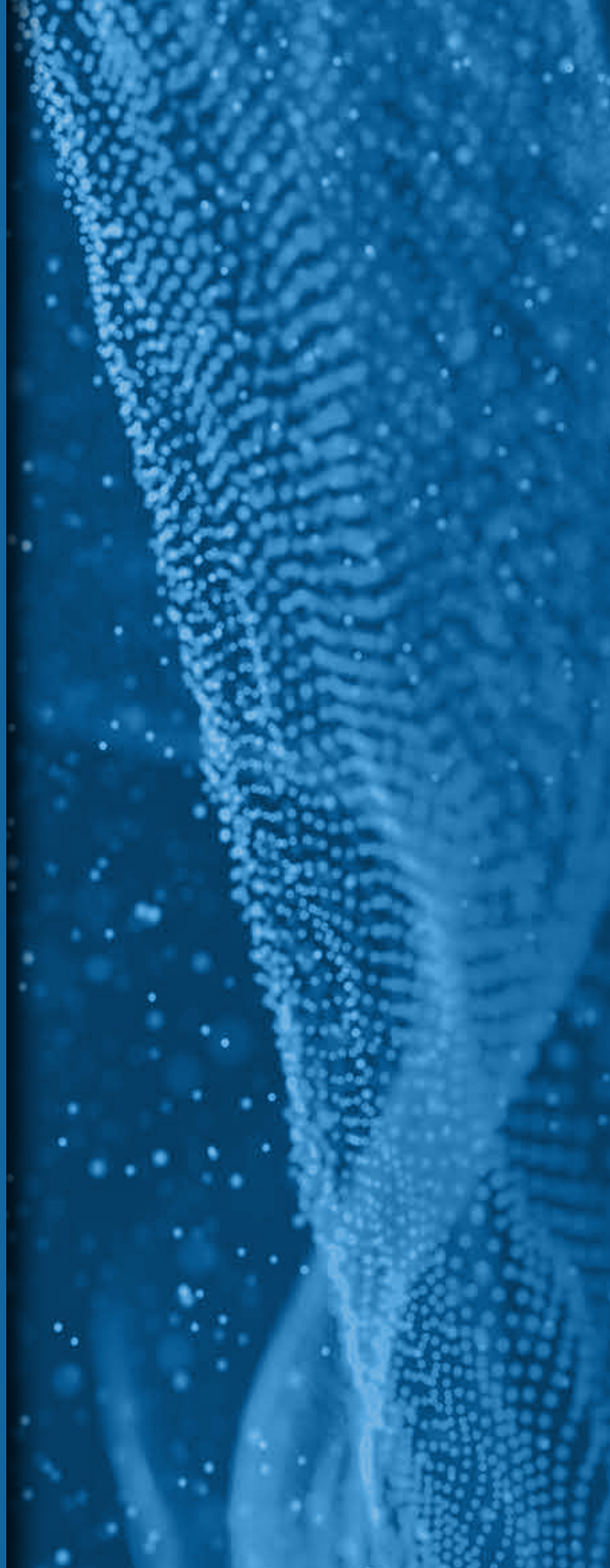
The Asian Productivity Organization (APO) is an intergovernmental organization that promotes productivity as a key enabler for socioeconomic development and organizational and enterprise growth. It promotes productivity improvement tools, techniques, and methodologies; supports the National Productivity Organizations of its members; conducts research on productivity trends; and disseminates productivity information, analyses, and data. The APO was established in 1961 and comprises 21 members.

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**EMERGING TRENDS IN APO MEMBERS:**

# **R&D PERFORMANCE TRENDS IN TURKIYE**

EMERGING TRENDS IN APO MEMBERS:  
R&D PERFORMANCE TRENDS IN TURKIYE

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# PREFACE

This publication on *Emerging Trends in APO Members* is aimed at enabling better navigation of the volatility, uncertainty, complexity, and ambiguity (VUCA) landscape. In today's turbulent, unpredictable world, the APO adopts a country-specific approach to understand and analyze emerging trends and driving forces that will have significant effects on member economies in terms of productivity and competitiveness. This series of reports introduces several emerging trends with the potential to disrupt and transform markets, governments, and society now and in the near future. It is hoped that through these publications analyzing those impactful trends, governments, policymakers, and ordinary citizens from all walks of life will be able to harness those driving forces while coping with critical uncertainties.

Recommended approaches and methods to address the challenges ahead include political, economic, social, technological, legal, and environmental perspectives. Being future-ready requires such a comprehensive approach to informed decision-making by governments, enterprises, and individuals in the fast-changing environment in the Asia-Pacific region. For the APO, it is all about early identification of issues and prospects, which requires strengthening its role as a think tank and regional adviser on productivity in the region.

The APO thanks all contributors to the report. We hope that it will benefit those seeking to improve productivity and quality of life brought about by emerging trends in a rapidly changing world.

# R&D PERFORMANCE TRENDS IN TURKIYE

## Abstract

The world economy is increasingly knowledge-based, making the role of research and development (R&D) vital for survival in this environment. R&D is a key component of innovation, and its positive impact on the competitiveness of countries and firms is widely regarded. In today's competitive environment, R&D activities are strategic for both firms and nations, prompting governments to subsidize R&D efforts of firms and institutes as part of their innovation policies. This study aims to analyze Turkiye's R&D performance based on internationally recognized indicators and evaluate the efficiency of its national R&D system based on official data. Firstly, the trends of R&D performance indicators, such as R&D personnel, expenditures, central government budget appropriations and outlays, tax incentives, and intellectual property, are presented. Then, the efficiency of R&D activities is assessed through basic input/output analysis. Finally, the findings are discussed.

## Introduction

The global economy increasingly operates in a knowledge-based environment, making R&D crucial for survival. Innovation studies emphasize on R&D as innovation is widely recognized for enhancing the competitiveness of nations and companies. R&D is the creative and systematic work done to expand the body of knowledge on society, culture, and humanity as well as to develop new applications for existing knowledge. In today's competitive landscape, R&D is a strategic endeavor for both firms and nations. As a result, governments support R&D initiatives through their innovation policies and provide financial incentives to institutions and companies.

R&D consists of creative and systematic efforts to increase the level of knowledge and apply it to new uses [1]. It is integral to innovation, which drives productivity and economic development. Innovation also serves as a powerful tool for creating new and better job opportunities, promoting social mobility, and addressing global challenges [2]. Through R&D and innovation activities, firms can strengthen their position in national and international markets by increasing their competitiveness. Therefore, carrying out R&D activities is essential for leveraging the economic growth brought on by technological advancements [3]. While large companies can often conduct R&D projects independently, small and medium-sized enterprises (SMEs), which make up a significant proportion of the economy, require greater government support and regulatory guidance in order to expand their R&D capabilities. For instance, Republic of Korea (ROK) employs R&D-based growth strategies that are specifically aimed at SMEs [4–5].

In Turkiye, R&D, innovation, and entrepreneurship policies were initially conducted primarily in universities. The synergy between industry and academia began to emerge in the 1990s, supported by the Scientific and Technological Research Council of Turkiye (TUBITAK). The Technology Development Foundation of Turkiye (TTGV) and Small and Medium Enterprises Development Organisation (KOSGEB) were established in 1990, marking the launch of initiatives supporting R&D projects in the commercial sector. Since the 2000s, policies have focused on boosting university-industry collaboration and promoting R&D partnerships, especially in high-tech sectors. In order to reduce R&D expenditures, the Technology Development Zones Law has facilitated the establishment of spaces where businesses in the private sector can collaborate with academic institutions. These efforts were further supported by research infrastructures, regional development agencies, and support programs, along with strategy papers and action plans. Key institutions, including the Ministry of



Industry and Technology (MoIT), TUBITAK, Council of Higher Education (YOK), KOSGEB, and the Ministry of Trade (MoT) have worked to encourage academics, researchers, businesses, and entrepreneurs to improve the nation's capacity for innovation.

Recognizing the positive contribution of R&D and innovation practices on national development, governments provide both direct and indirect support for these activities. In Türkiye, most of the support and incentives in this area are provided through public institutions and organizations. In terms of scope, the supports provided in Türkiye can be broadly divided into two main categories: project-based and institutional-level assistance. According to the National Innovation System 2028 Targets, Türkiye aims to increase the ratio of R&D expenditures to 2.05% of GDP and boost the number of researchers to 335,000 full-time equivalents by 2028.

This study's objective is to analyze the R&D performance of Türkiye based on internationally recognized indicators and evaluate the efficiency of its national R&D system. It begins by examining the trends in R&D performance indicators, such as personnel, expenditures, central government budget appropriations and outlays, tax incentives, and intellectual property (IP). It then assesses the efficiency of R&D activities.

This study is structured as the following: first the theoretical background of R&D, innovations, and national innovation system is discussed. Türkiye's R&D performance is then analyzed annually based on several input and output indicators. Subsequently, the efficiency of Türkiye's R&D system is evaluated. Finally, the study concludes with a discussion of findings.

## Theoretical Background

### R&D

R&D can be defined as creative endeavors carried out on a systematic basis to increase knowledge, encompassing human, cultural, and social knowledge, and the utilization of this stock of knowledge to design new applications [1]. It includes the studies carried out according to scientific principles and its results to create new products, improve product quality, adopt new techniques, develop cost-reducing production technologies, adapt advanced technologies to existing conditions in the country, improve existing technologies, and integrate new technologies into existing frameworks [6].

Three distinct applications are included in R&D activities: basic research, applied research, and experimental development. Without considering a particular and special application or usage, basic research is based on theoretical or experimental studies aimed at gaining new understanding of the underlying phenomena and observable situations. Applied research encompasses activities with the main goal of generating original knowledge with a clear practical objective. Experimental development is the systematic process of producing new materials, products, circuits, systems, processes, or services, or significantly improving those already produced or created through research and/or practical experience [7].

The most critical sources of stable economic growth targeted by countries are technological progress and development. These technological breakthroughs are made possible through the accumulation of knowledge via R&D activities [8]. Technological innovations that emerge as a result of R&D efforts enhance firms' competitiveness and contribute to increased market shares and profitability. They also elevate productivity and ensure more efficient and sustainable use of resources [9]. This process drives industrial development, ultimately leading to economic growth.

For developing countries, increasing the share of high-technology exports in total exports is a necessity due to the high added value they generate. In addition, an analysis of differences in per capita income and economic growth highlights the critical roles of technological infrastructure, natural resources, human capital, labor productivity, and economic and political stability. At this point, to compete with developed nations, developing countries must provide incentives to enhance technology transfer, increase education spending, and boost R&D investments [10].



R&D expenditures play a vital role in stimulating economic growth [11]. At the macroeconomic level, investments realized within the scope of R&D initiatives transform the diminishing returns caused by externalities and spillovers into increasing returns. R&D expenditures stand out as a crucial strategy for driving innovation and fostering economic growth. They attract foreign direct capital investments into the nation while also aiding in the advancement of technological capabilities, and promote domestic technology development while reducing reliance on external technology [12].

The fact that the outputs obtained through R&D are public goods and the high rate of social return indicates that there are significant externalities related to R&D investment suggests that privately financed R&D may be insufficient and might require direct or indirect support from the state [13]. Public support for R&D activities is the cornerstone of innovation policies implemented by many countries. The main objective of these policies is to increase the innovation potential and boost the competitiveness of the economy [14].

### Innovation

Innovation is defined as the realization of a new or significantly improved product (goods or services), or process, a new marketing method, or a new organizational method in internal practices, workplace organization, or external relations [15]. Although R&D is an activity that supports innovation, not all innovation activities are directly linked to R&D. This is because R&D efforts may fail to generate value if those conducting them lack entrepreneurial qualities, which limit their ability to convert research into economic and social benefits. Nonetheless, R&D activities are a vital component of innovation activities [16].

Although science and technology are integral to every step of the innovation process, the final concept or product needs to be commercially viable and deliver tangible outcomes. Participation from all individuals and organizations within the scientific and economic spheres in society is essential. A nation should have a national policy on innovation even though regional initiatives are the main drivers of invention [17].

Innovation is categorized into four types: product innovation, process innovation, marketing innovation, and organizational innovation.

- **Product innovation** refers to the introduction of entirely new or significantly improved goods or services based on existing characteristics or anticipated usage patterns. It typically includes notable advancements in technical specifications, materials and components, integrated software, user-friendliness, and additional functional features
- **Process innovation** involves the development of a novel or significantly improved manufacturing or delivery method. It encompasses major modifications to processes, tools/equipment, and/or software stages, made possible through the adoption of innovative approaches
- **Marketing innovation** is defined as "a new marketing method involving significant changes in product design or packaging, product positioning, product promotion, or pricing"
- **Organizational innovation** refers to the implementation of a new organizational method in a firm's business practices, workplace organization, or external relations [15]

### National Innovation System

An innovation system refers to the collaboration involving private and public enterprises, universities, research institutions, and government bodies, both private and public, aimed at developing innovations that align with the needs of consumers for new or improved products and services [18]. In other words, an innovation system can be defined as the institutions and policies that influence the content of new technologies within the economy and the communication networks that connect these entities [19].

Various concepts, such as global innovation systems, national innovation systems, regional innovation systems, sectoral innovation systems, and technological innovation systems, have been developed to

describe different types of innovation systems, which are interconnected. The national innovation system consists of numerous national-level elements, including infrastructure, institutions, the education and training system, the financial system, governance structures, and the interlinkages among these components [20].

The national innovation system is defined as a cluster of institutions that shape the innovation performance of national enterprises through their interactions. It is recognized as a key element of national competitiveness, growth, and profitability [21]. The national innovation system can be described as a complex network of innovation actors and institutions directly involved in the absorption, diffusion, and production of technological innovation as well as the interrelationship between them, including public research institutes, academia, and industry working collaboratively to realize innovation [22].

Efforts to establish Türkiye's national innovation system began with the establishment of the State Planning Organisation in 1962 and TÜBİTAK to guide science and technology activities in the country with the First Five-Year Development Plan. The Second and Third Five-Year Development Plans focused on technology transfer and technological development while the Fourth Five-Year Development Plan emphasized on integrating technology policies with industrial, investment, and employment policies, which highlighted the need for certain sectors to develop their own technologies. However, an analysis of the science and technology policies of the 1960s and 1970s shows that they primarily supported basic and applied research in the natural sciences [23].

During the 1963–80 period, following the establishment of TÜBİTAK at the beginning of the period and later the Marmara Research Centre (MAM), priority was given to basic research, especially in universities and public institutions. Although Türkiye made positive strides in science and technology indicators during the 1980s and 1990s, the contribution of these advances to the country's production structure, export performance, and competitiveness remained limited [24].

Between 1994 and 2004, important developments took place in order to support the development of the science and technology system and to establish its legal and institutional infrastructure. This included the establishment of the Turkish Patent Institute (TPI), the Turkish Accreditation Board (TÜRKAK), the signing of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, the University Industry Joint Research Centre Programme (USAMP), the National Metrology Institute (UME), the Small and Medium Industry Development and Support Administration (KOSGEB). Other milestones included the enactment of the Law on Technology Development Zones and the formation of the Technology Development Foundation of Türkiye (TTGV) [25].

Türkiye's major policy document, the Development Plans, outline the fundamental governmental policies for five-year intervals, which have been instrumental in shaping the innovation landscape. The Tenth Development Plan (2014–18) focused on "Innovative Production, Stable High Growth" and divided policy goals into four primary categories. The plan's overarching goal was to raise the R&D spending to GDP ratio to 1.8%. Türkiye's overarching goal was to enhance the nation's economic and technological independence while improving its worldwide competitiveness through the implementation of policies outlined in the "National Technology Move" vision. The defense sector has been the first to successfully adopt this vision; this has boosted domestic suppliers' capacity to produce advanced technologies, efficient cost-cutting measures, and demonstrated their ability to develop cutting-edge new products, such as drones, missiles, radar systems, and satellites.

The Eleventh Development Plan (2019–23), entitled "Competitive Production and Productivity," further defined targets and measures for advancing R&D and innovation, reinforcing Türkiye's commitment to advancing a dynamic national innovation system [26].

## R&D and Innovation Performance in Turkiye

Depending on the structure of their national innovation systems, countries demonstrate their performance in R&D and innovation through various indicators. In this section, Turkiye's R&D and innovation performance over the years is presented as well as how it compares with other countries.

Firstly, Turkiye's position in the Global Innovation Index (GII) will be analyzed. The GII ranks global economies according to their innovation capabilities and is prepared annually in cooperation with the World Intellectual Property Rights Organisation (WIPO), INSEAD, and Cornell University. The goal of the GII is to establish best practices, promote targeted regulations, and foster a culture of ongoing assessment of innovation features. It is comprised of four metrics: the overall GII score, input subindices, output subindices, and innovation effectiveness ratio. It also contributes to the development of superior strategies and programs. As a result, this index provides an explanation for a metric application that encompasses numerous economies annually. However, rather than focusing solely on comparing capacities, it aims to highlight a nation's strengths and weaknesses in terms of innovation-related policies and practices [27–28].

According to the GII 2023 results, the top 10 countries are Switzerland, Sweden, the United States of America (USA), the United Kingdom, Singapore, Finland, the Netherlands, Germany, Denmark, and the ROK. Turkiye ranked 39th among 132 countries in the overall ranking. In addition, Turkiye ranks fourth among 34 upper-middle-income countries and is considered one of the leading countries on the development line in this group. It also ranked fourth among the countries in the North Africa and West Asia group.

Turkiye's rankings in the GII from 2014 to 2023 are presented in Figure 1, showing that the country has significantly improved its performance in the last 10 years.

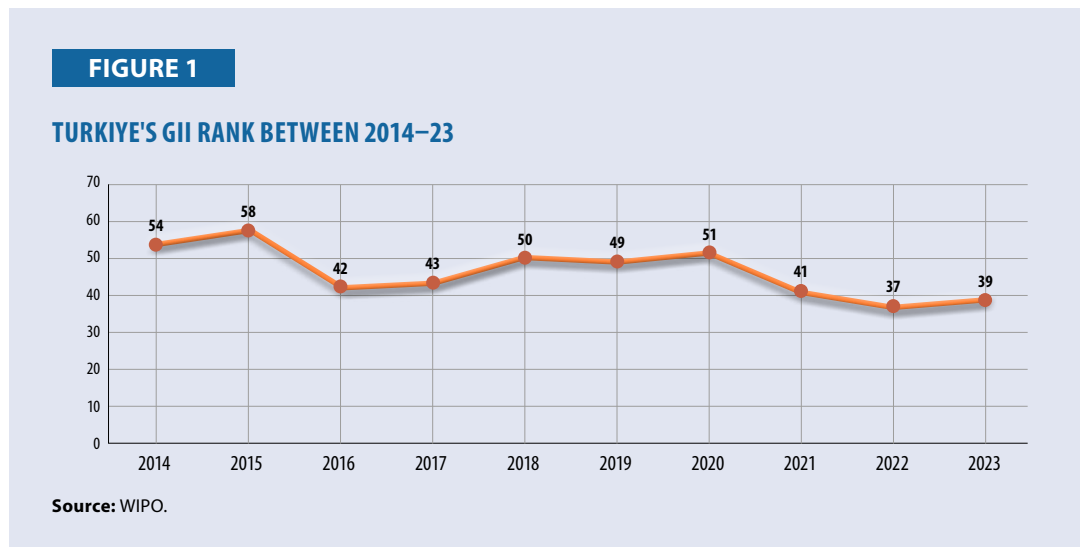


Table 1, in the meantime, presents Turkiye's rankings in terms of the GII indicators. They provide insights into the factors contributing to the changes in its performance. Over the past decade, Turkiye has improved its rankings in human capital and research, infrastructure, market sophistication, business sophistication, and creative outputs indicators while its ranking in the institutions indicator has declined. The knowledge and technology outputs indicator has remained relatively stable.

**TABLE 1**

**TURKIYE'S RANKINGS ACROSS THE GII INDICATORS**

GII Indicators	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Institutions	92	84	82	95	96	85	94	93	101	105
Human capital and research	54	50	43	43	49	46	42	26	41	41
Infrastructure	75	63	62	68	52	41	54	48	48	50
Market sophistication	63	58	46	57	55	52	28	49	37	36
Business sophistication	110	117	86	75	72	71	57	46	47	46
Knowledge and technology outputs	48	60	45	46	52	59	57	50	47	44
Creative outputs	40	37	31	31	39	40	50	35	15	27

Source: WIPO.

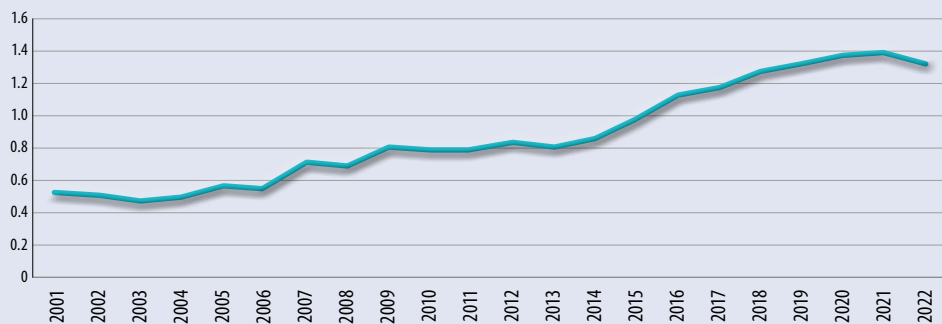
Following this assessment, Turkiye’s R&D and innovation performance will be analyzed dynamically by using the indicators listed in the following:

- Gross domestic expenditure on R&D as a percentage of GDP
- Distribution of R&D Expenditures as a percentage of GDP by institution
- Total R&D personnel full time equivalent (FTE)
- Central government budget appropriations and outlays on R&D
- Indirect government support through R&D tax incentives
- Total number of granted patents
- Medium- and high-tech exports (percentage of manufactured exports)

Figure 2 shows Turkiye’s gross domestic expenditure on R&D as a percentage of GDP. Over the past 22 years, Turkiye’s R&D expenditure level relative to GDP shows a steady increase, surpassing 1% since 2016 and reaching 1.32% in 2022.

**FIGURE 2**

**GROSS DOMESTIC EXPENDITURE ON R&D AS A PERCENTAGE OF GDP (2001–22)**



Source: Turkish Statistical Institute (TURKSTAT).

Distribution of R&D expenditures as a percentage of GDP by institution is illustrated in Figure 3. Between 2001 and 2022, the share of business R&D expenditures as a percentage of GDP has increased from 0.18% to 0.81%. Meanwhile, the share of government R&D expenditures as a percentage of GDP remained stable, fluctuating between 0.04% and 0.10%. The share of higher education R&D expenditures as a percentage of GDP has increased slightly from 0.31% in 2001 to 0.45% in 2022. The significant increase in the share of business R&D expenditures is the result of grants and incentives provided to businesses through various R&D and innovation programs, especially those by TUBITAK and KOSGEB over the last 22 years.

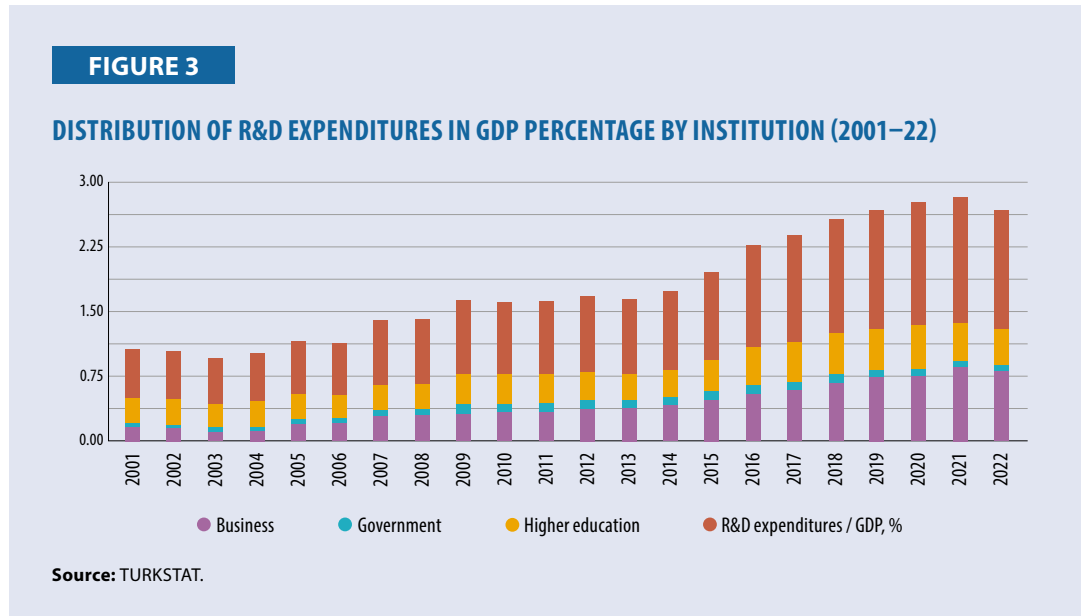
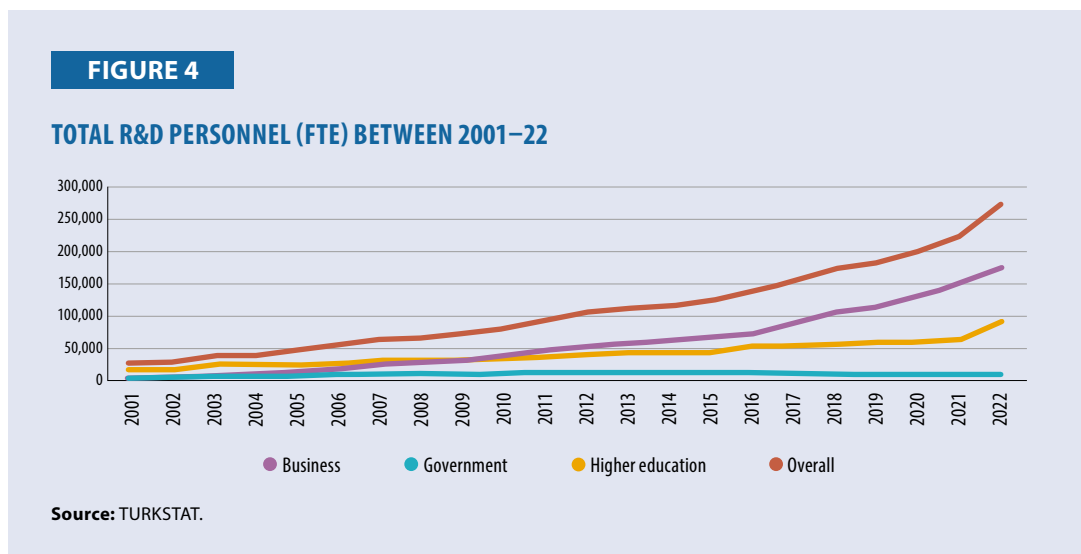


Figure 4 presents the total R&D personnel in FTE, showing an overall increasing trend. When analyzed in terms of business, government, and higher education sectors, it is seen that total R&D personnel in the business sector has the highest growth, with an increase of 2,978% from 2001 to 2022. This is in comparison to 82% in government and 438% in higher education in the same period. As a result of the rise in R&D expenditure in the business sector, the number of R&D personnel had also increased. Most of them are employed in R&D centers of firms and companies located in Technology Development Zones (TDZs).



Turkiye’s total government budgetary allocations for R&D as a percentage of GDP compared with OECD countries, the USA, and EU-27 countries between 2008 and 2022 is presented in Figure 5. In Turkiye, these allocations (as a percentage of GDP) increased annually until 2013 but have not returned to that peak level in subsequent years. Between 2008 and 2023, the total increase rate for Turkiye’s government budgetary allocations for R&D as a percentage of GDP was 35%. The average for OECD countries during this period was 0.681% while the USA at 0.721%, EU-27 countries at 0.677%, and for Turkiye, 0.375%.

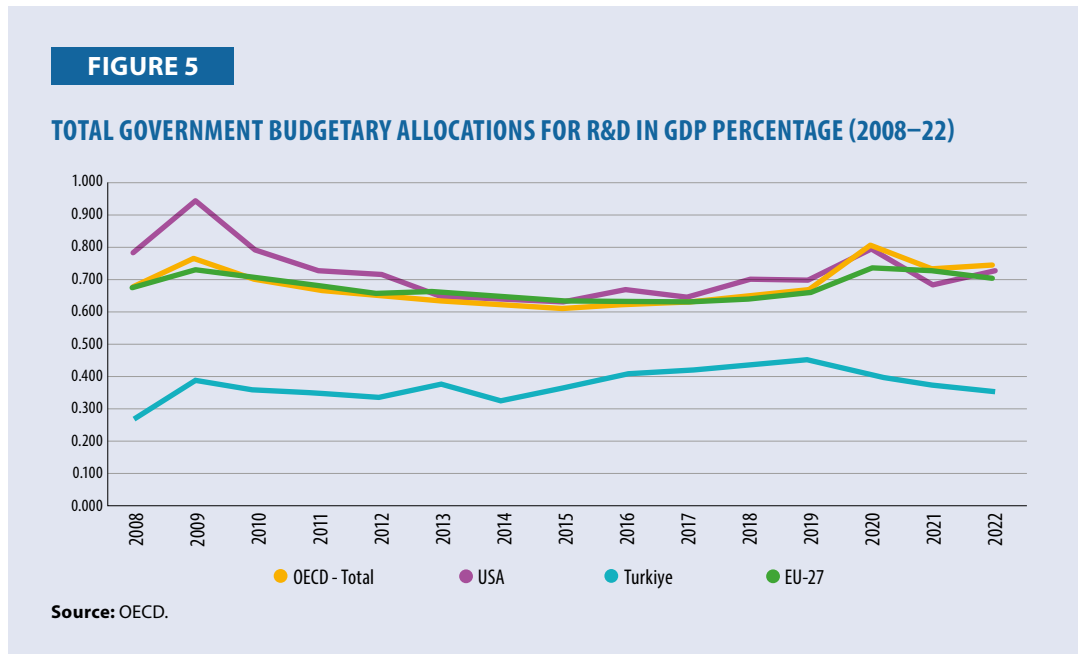
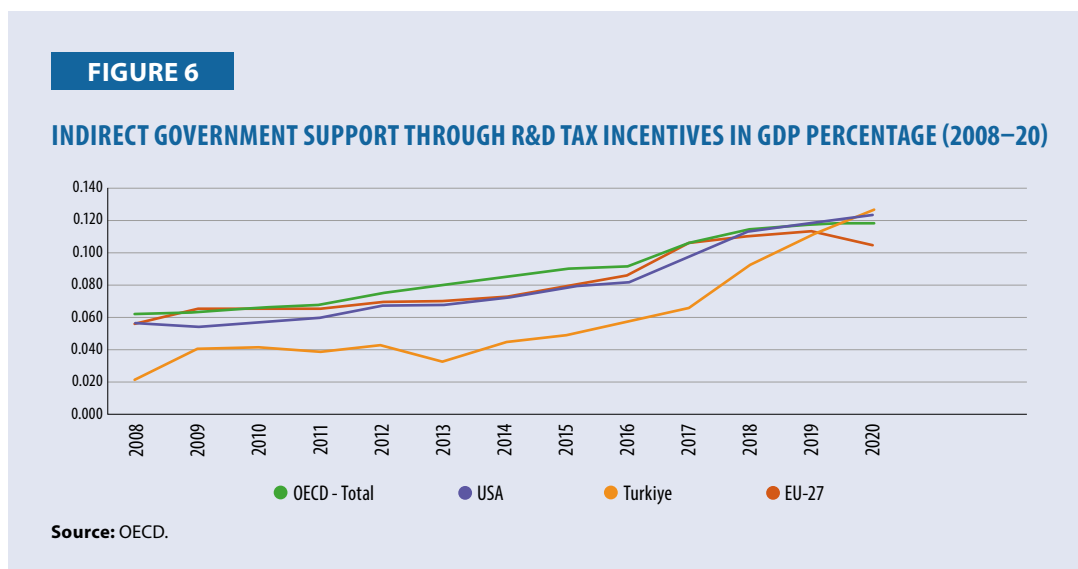
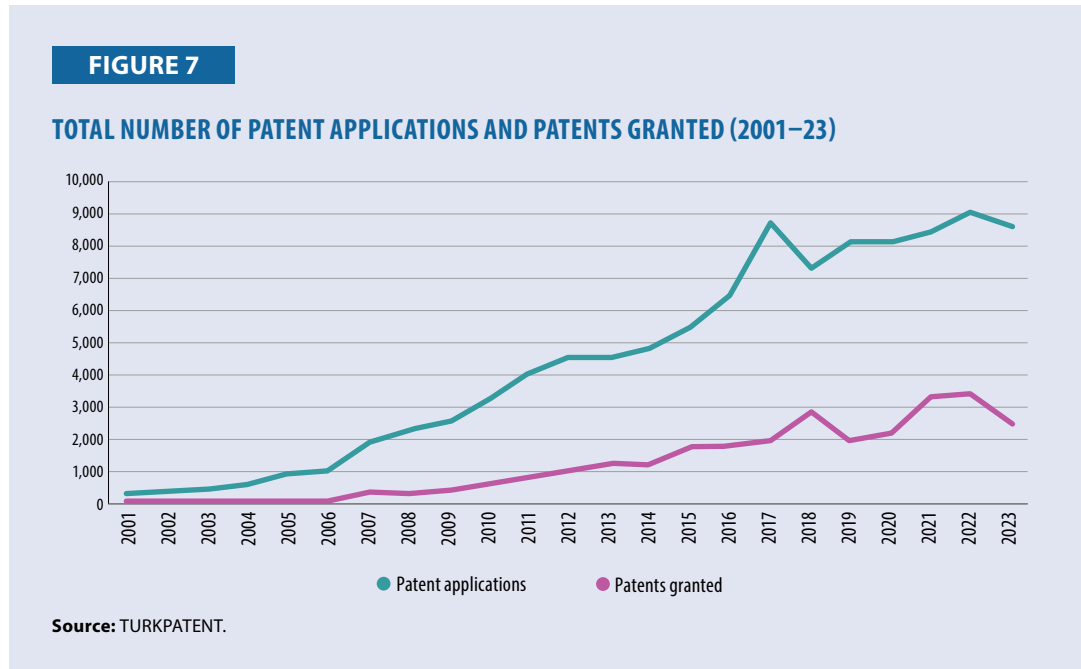


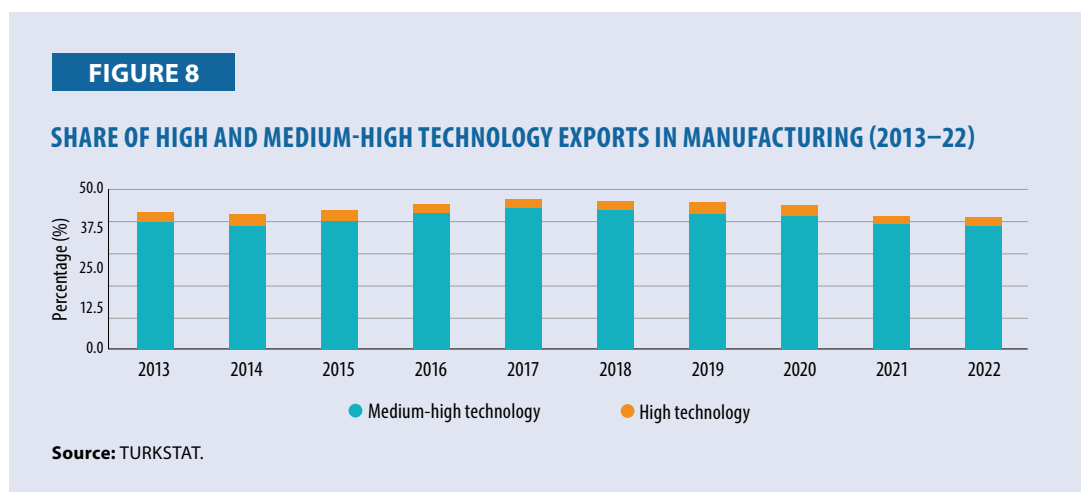
Figure 6 compares Turkiye’s indirect government support through R&D tax incentives as a percentage of GDP of Turkiye with OECD countries, the USA, and EU-27 countries between 2008 and 2020. R&D tax incentives are one of the key policy instruments to foster R&D activities in economies. Accordingly, since 2013, Turkiye has steadily increased its indirect government support through R&D tax incentives, reaching parity with OECD countries, the USA, and EU-27 countries by 2020.



The total number of patent applications and patents granted for the period of 2001–23 is shown in Figure 7. Patent applications and patents granted are important indicators for assessing the success of R&D and innovation efforts. There is a rapid increase in both patent applications and patents granted to domestic entities up to 2017, followed by fluctuations during the 2017–23 period. The overall trend suggests that R&D and innovation activities are producing results of higher quality and that researchers and companies are becoming increasingly aware of the importance of protecting intellectual and industrial property rights.



Another significant indicator is the share of manufacturing exports with high and medium-high technology. It is expected that R&D and innovation will increase the technological intensity of a country's exports. Figure 8 shows the share of high and medium-high technology exports in manufacturing exports for Turkey. Despite increases in R&D expenditures, R&D human capital, and granted patents, Turkey has not significantly raised its share of high and medium-high technology manufacturing exports. The combined share of these two categories has not surpassed 45% between 2013 and 2022. This may be due to insufficient commercialization of new inventions and a lag in the diffusion effects of new innovations.

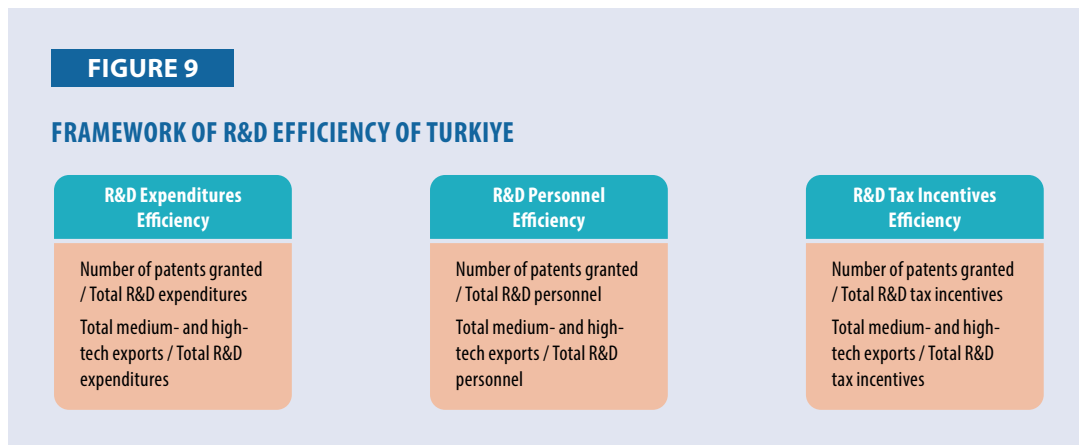




## R&D Efficiency in Turkiye

R&D and innovation are regarded as vital components for economic growth, sustainable development, and competitiveness. They have become central to national goals and growth strategies. Utilizing the resources that facilitate innovation activities as effectively as possible is crucial, as is encouraging innovation and promoting the dissemination of new products and procedures across the nation. The performance of a national innovation system cannot be solely determined by the quantity and quality of innovation outputs produced. It must also consider the effective use of resources for innovation, which enables innovation activities to produce meaningful outputs. Efficient use of innovation resources significantly contributes to achieving countries' growth objectives and sustainable development goals [29].

In the previous section, Turkiye's R&D trends were evaluated using seven indicators. Inputs included gross domestic expenditure on R&D as a percentage of GDP, the distribution of R&D expenditures as a percentage of GDP by institution, total R&D personnel (FTE), total government budgetary allocations for R&D as a percentage of GDP, and R&D tax incentives. Outputs consisted of the total number of patents granted and the share of medium- and high-tech exports in manufactured exports. However, increases or decreases in inputs and outputs alone may not accurately reflect the real situation. For this reason, this section examines the efficiency of total R&D expenditures, total R&D personnel, and total R&D tax incentives in terms of the number of patents granted and total medium- and high-tech exports (Figure 9). By using the national resources efficiently allocated to R&D and innovation activities, it is expected that the efficiency of R&D and innovation activities will increase.



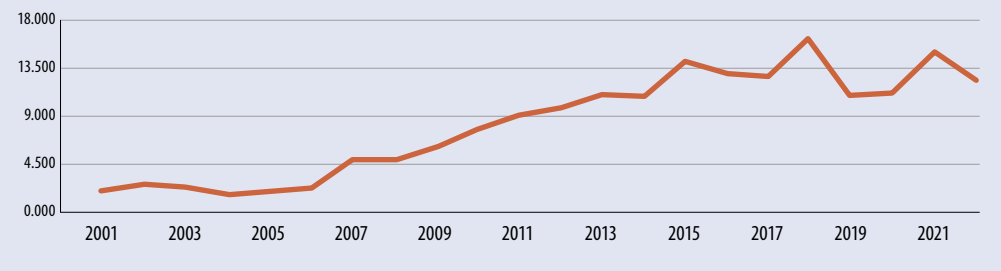
Figures 10–15 features the efficiency of Turkiye's R&D expenditures, R&D personnel, and R&D tax incentives. The monetary values are in USD to eliminate the effects of inflation in the Turkish lira (TRY). Both R&D personnel efficiency and R&D expenditures efficiency, measured in terms of patents granted, show an increasing trend. This indicates that as R&D expenditures and personnel numbers grow, the number of patents granted rises at a greater rate.

However, R&D personnel efficiency in terms of total medium- and high-tech export exhibits a declining trend while R&D expenditures efficiency for these exports remains stable. This suggests that Turkiye's national innovation system struggles with the commercialization of the R&D outcomes.

As for R&D tax incentives, there is a slight decreasing trend in terms of efficiency for patents granted and a more pronounced decline in efficiency for total medium- and high-tech export. Although Turkiye has steadily increased its R&D tax incentives, these efforts have not yet produced sufficiently impactful results.

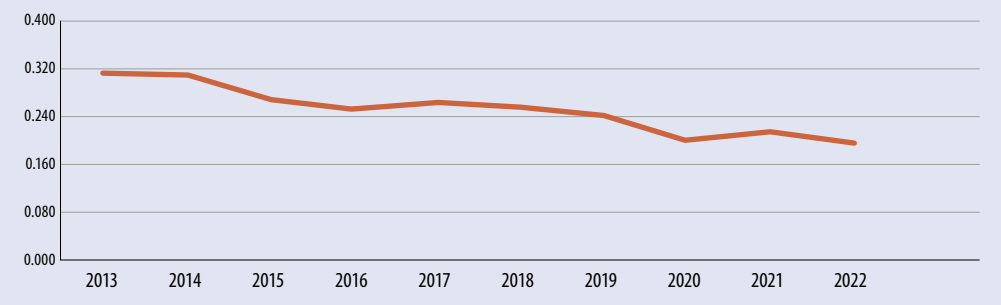
**FIGURE 10**

**R&D PERSONNEL EFFICIENCY (NUMBER OF PATENTS GRANTED/TOTAL R&D PERSONNEL) (2001-21)**



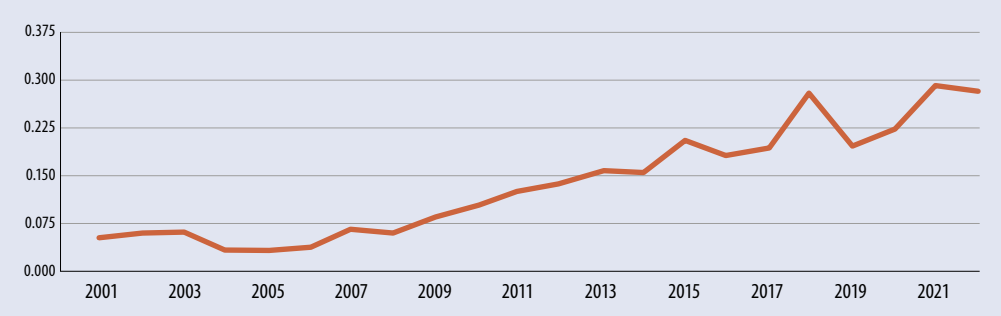
**FIGURE 11**

**R&D PERSONNEL EFFICIENCY (TOTAL MEDIUM- AND HIGH-TECH EXPORTS/TOTAL R&D PERSONNEL) (2013-22)**



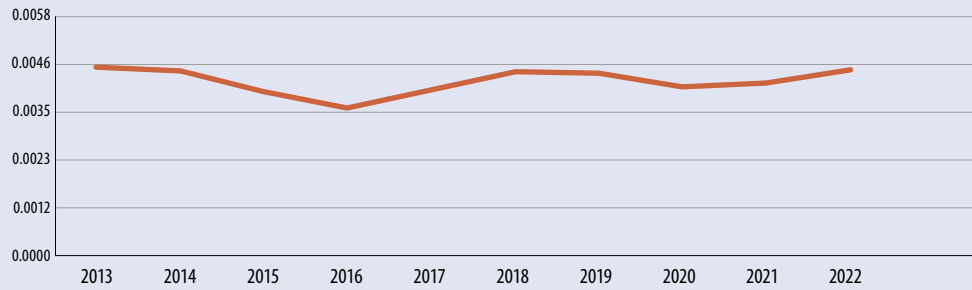
**FIGURE 12**

**R&D EXPENDITURES EFFICIENCY (NUMBER OF PATENTS GRANTED/TOTAL R&D EXPENDITURES) (2001-21)**



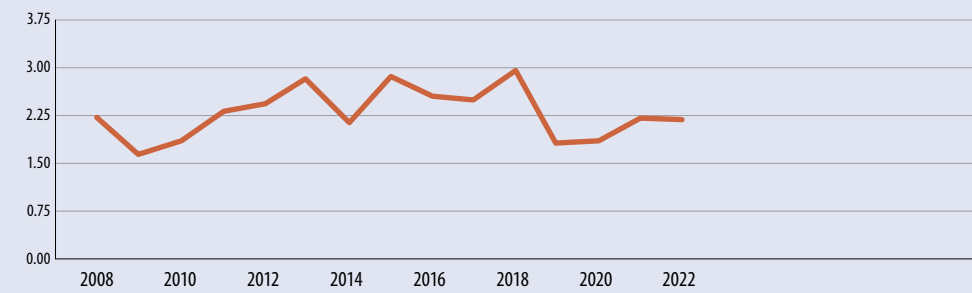
**FIGURE 13**

**R&D EXPENDITURES EFFICIENCY (TOTAL MEDIUM- AND HIGH-TECH EXPORTS/ TOTAL R&D EXPENDITURES) (2013–22)**



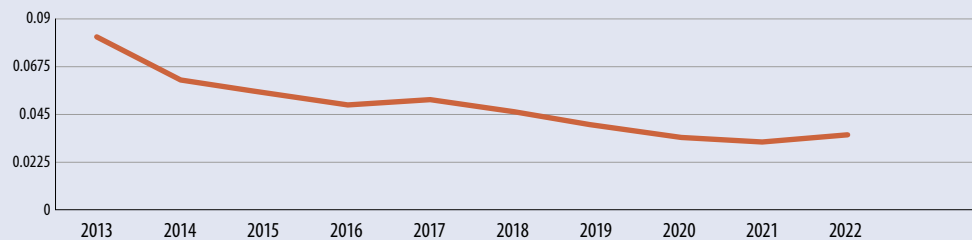
**FIGURE 14**

**R&D TAX INCENTIVES EFFICIENCY (NUMBER OF PATENTS GRANTED / TOTAL R&D TAX INCENTIVES) (2008–22)**



**FIGURE 15**

**R&D TAX INCENTIVES EFFICIENCY (TOTAL MEDIUM- AND HIGH-TECH EXPORTS/ TOTAL R&D TAX INCENTIVES) (2013–22)**



## Conclusion

It is widely accepted that technological changes play an important role in achieving sustainable economic growth. As a result, the majority of nations have made significant investments in R&D activities both financially and in terms of labor. The need for effective R&D endeavors is further heightened by the limited availability of resources for this type of work [30]. This study examines Türkiye's R&D performance trends. First, the changes in input and output indicators were analyzed, followed by an evaluation of the efficiency of R&D activities. Analyzing inputs and outputs separately does provide a comprehensive understanding of R&D performance.

In this study, Türkiye's performance in the GII was first presented, and then the country's R&D performance was examined by looking at various indicators: (i) gross domestic expenditure on R&D as a percentage of GDP; (ii) distribution of R&D expenditures as a percentage of GDP by institution; (iii) total R&D personnel (FTE); (iv) central government budget appropriations and outlays for R&D; (v) indirect government support through R&D tax incentives; (vi) total number of granted patents; (vii) medium- and high-tech exports as a percentage of manufactured exports. The analysis shows that Türkiye has improved its GII rank in last 10 years. Türkiye's R&D expenditure level relative to GDP has increased from 0.51% to 1.32%, and the share of business R&D expenditures as a percentage of GDP has risen from 0.18% in 2001 to 0.81% in 2022. The total number of R&D personnel (FTE) grew from 27,698 to 272,638 over the past 21 years. Central government budget appropriations and outlays for R&D increased by 56% between 2008 and 2023, and indirect government support through R&D tax incentives rose by 459% from 2008 to 2022.

As for outputs, there has been an increasing trend in the total number of patent applications and patents granted from 2001 to 2023. However, Türkiye has not significantly boosted its share of high and medium-high technology manufacturing exports, despite increases in R&D expenditures, human capital, and granted patents. The combined share of high technology and medium-high technology exports in manufacturing exports has not surpassed 45%.

To gain a more comprehensive understanding of Türkiye's R&D performance, the efficiency of R&D expenditures, R&D personnel, and R&D tax incentives were examined. These efficiency measures were calculated in terms of number of patents granted and total medium- and high-tech exports. In terms of number of patents, both R&D expenditures efficiency and R&D personnel efficiency show an increasing trend while R&D tax incentives efficiency remains stable. But in terms of total medium- and high-tech exports, R&D personnel efficiency and R&D tax incentives efficiency show a declining trend, and R&D expenditures efficiency remains relatively stable.

Based on the efficiency analysis, it was concluded that two problematic areas emerge in Türkiye's national innovation system. First, the efficiency performance in terms of total medium- and high-tech exports is lower than that of total patents granted. This suggests that technology transfer activities related to R&D outputs are not effective in Türkiye. Second, R&D tax incentives efficiency shows low performance in both total medium- and high-tech exports and number of patents granted, indicating that the program design and management of R&D incentives are not fully effective.

In order to transfer knowledge and innovation for commercial and public benefit, an institutional mechanism is required. This is facilitated by a technology transfer office (TTO), a semi-independent organization tasked with identifying innovations with the greatest potential for substantial beneficial effects and determining the best strategy to assist their growth [31]. To enhance Türkiye's R&D performance outcomes, current technology transfer mechanisms must be improved. For Türkiye, the challenge in medium- and high-tech exports means the patents produced cannot be licensed and commercialized effectively. Currently, there are more than 100 TTOs in universities and technology development zones (TDZs) across Türkiye. These TTOs should be empowered to work effectively and the quality of human resources within them must be improved.

Evaluating the effectiveness of public sector support and incentives is crucial. These evaluations provide benefits in many aspects, such as the efficient use of resources, ensuring accountability and

transparency, guiding policymaking, measuring economic and social contributions, and identifying areas for improvement. Therefore, measuring the impact of public support plays a critical role in refining existing programs and establishing more effective support mechanisms in the future. In Türkiye, there are some studies on the impact of R&D support and incentives, such as those from KOSGEB and TUBITAK R&D (2021), techno-enterprise capital support (2021), design support (2021), regional investment incentives, research infrastructures, and the patent support program. According to these studies, the support and incentives provide a positive effect on employment and domestic sales. However, their impact on exports and patents is relatively lower [32]. To increase the efficiency of R&D tax incentives, these programs should be revised and redesigned based on the findings of impact evaluation studies.

In conclusion, focusing solely on the inputs and outputs of a national innovation system may obscure the underlying issues. Adopting a more comprehensive approach can provide better results. By measuring R&D performance and striving to improve the outcomes, Türkiye can advance into the league of high-income countries. Furthermore, there may be some potential challenges or barriers that Türkiye may face in implementing the technological innovation to improve its productivity, such as firms may have insufficient level of awareness, the need for financing and support for high-level investments, and an unqualified workforce for new technologies. To overcome these challenges and barriers, the number and scope of thematic support and incentives programs, such as Technology Focused Industrial Move Program, which aims to increase the production of medium-high and high technology, high value-added products critical for the development of these sectors in Türkiye should be expanded as well as boosting new production opportunities and capabilities to the country.

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# ABBREVIATIONS AND ACRONYMS

FTE	Full-time equivalent
GDP	Gross domestic product
GII	Global Innovation Index
KOSGEB	Small and Medium Enterprises Development Organisation
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
ROK	Republic of Korea
SMEs	Small and medium-sized enterprises
TRY	Turkiye's currency "Lira"
TTGV	Technology Development Foundation of Turkiye
TTO	Technology transfer office
TUBITAK	Scientific and Technological Research Council of Turkiye
TURKSTAT	Turkish Statistical Institute
USA	United States of America
WIPO	World Intellectual Property Rights Organisation

