

Received: 14/05/2026

Accepted: 02/06/2026

Published: 30/06/2026

BEYOND ASSEMBLY: A STRUCTURAL EVALUATION OF TÜRKİYE'S INNOVATION CAPACITY AND TECHNOLOGY TRANSFER FRAMEWORKS

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Abstract

Technology remains fundamental for national economic stability and global standing, creating a clear structural divide between advanced, knowledge-producing economies and developing, technology-importing nations. Developing countries strategically pursue cross-border technology transfer to reduce execution gaps, enhance industrial capacity, and accelerate macroeconomic growth. This study evaluates Türkiye's technology transfer mechanisms, analyzing the evolution of its national innovation ecosystem through critical macro-level indicators—specifically public-private R&D expenditures, patent applications, and high-tech manufacturing frameworks—while assessing the operational roles of technoparks and Foreign Direct Investment (FDI). Despite Türkiye's remarkable quantitative progress in expanding its scientific infrastructure and scaling its total researcher capacity, a persistent structural challenge remains in efficiently converting registered intellectual property into commercialized, high-value manufacturing and sustainable high-tech export volumes. To break out of import-heavy assembly dependencies and achieve genuine technological sovereignty, this conceptual review stresses the vital need for expanding qualitative R&D funding models, enforcing systemic brain drain prevention strategies, and actively transforming transactional technology procurement into deep-tech indigenous production pipelines. Synthesizing these micro and macro dynamics, the paper outlines the institutional misalignments and structural bottlenecks that currently complicate national technology management processes.

Keywords: Technology Transfer, Technology Management, R&D Frameworks, University-Industry Integration

Introduction

Economic growth and social prosperity today hinge on a nation's ability to generate and apply knowledge and technology. Since the Industrial Revolution, nations with robust R&D and advanced infrastructure have dominated high-value technology sectors, while countries unable to adapt remain dependent on external sources. Developed countries excel in advanced technology production (TÜBİTAK, 2004; Gür, 2014), whereas developing nations often rely on technology transfer to bridge the gap (Hamitoğulları & Uras, 1974; Karacasulu, 2000). Technology transfer is not just about importing technology; it involves adapting, developing, and maintaining it within local conditions (Kiper, 2004; Akçaoğlu, 2002; Tiryakioğlu, 2011; Dizdar, 2019).

For developing nations, technology transfer is a crucial development tool (Seyidoğlu, 2009; Malatyalı, 2016). However, excessive reliance can create long-term dependency



Erdoğan Alkan, A. (2026). Beyond assembly: A structural evaluation of Türkiye's innovation capacity and technology transfer frameworks. *Social Research and Education Journal*, 2(1), 35-51.
<https://doi.org/10.5281/zenodo.21428076>



(Tiryakioğlu, 2011). Thus, technology transfer should be understood as a process of learning, adapting, and developing domestic capacity, not just acquisition (Koca, 2013; Dizdar, 2019).

Türkiye, a developing country, has long relied on technology transfer to meet its technological needs (Demir, 1986; Karacasulu, 2000). Strengthening its domestic technology production is vital for Türkiye to sustain economic growth, boost international competitiveness, and reduce technological dependence (Şahin, 2011; Soyak, 2008). Various science and technology policies have been implemented over time, including R&D development, university-industry collaboration, technopark establishment, and foreign capital incentives (DPT, 1984; DPT, 1995; Ministry of Industry and Trade, 2010). While some policies contributed to technology capacity, others did not achieve expected success (Yalçıntaş, 2014; Eyyuboğlu and Aktaş, 2016).

This study aims to analyze Türkiye's technology management and transfer processes through macroeconomic indicators, highlighting the transformative roles of university-industry collaboration and foreign direct investment. This is a conceptual review based on existing literature.

Method

This study is designed as a qualitative conceptual review and a macro-level structural analysis based on an extensive literature matrix. The research systematically evaluates the contemporary architectural dynamics of Türkiye's national innovation ecosystem and technology transfer pathways. The methodological framework of the study is constructed upon a secondary data analysis approach, integrating official macro-economic development indicators, international trade reports, and legislative milestones implemented within the national framework.

To trace the qualitative and quantitative evolution of technology management channels, the study specifically examines three interconnected parameters: national research and development (R&D) expenditures as a share of gross domestic product (GDP), the expansion of highly skilled human capital and total full-time equivalent researcher capacity, and the volume and industrial commercialization efficiency of intellectual property outputs through patent applications. These macro-level indicators are cross-analyzed chronologically against the strategic goals outlined in the state development plans and scientific institution frameworks.

Furthermore, the study utilizes the established theoretical principles of the "Triple Helix Model" to evaluate the structural efficacy of university-industry collaborations, technology transfer offices (TTOs), and technopark ecosystems. By juxtaposing the practical operational trends of Foreign Direct Investment (FDI) against local absorptive capacities, the qualitative analysis uncovers systemic barriers—such as the regional brain drain and the persistence of import-heavy assembly models—that limit authentic domestic knowledge generation. Consequently, the research relies on synthesis, critical evaluation, and vision-oriented policy projection rather than statistical empirical experimentation, providing an end-to-end institutional evaluation of the nation's technology management trajectory.

Macro Indicators Of Technological Development And The 2026 Projection

To illustrate Türkiye's innovation and technology transfer performance, the historical development of key macroeconomic data, which are the outputs of the national R&D ecosystem, and their current levels as of 2026 are analyzed below:

Conceptual Framework of Technology and R&D Dynamics

Macroeconomic indicators of a nation's innovation capacity are inherently tied to how effectively it manages its technological capital. Globally, R&D spending serves as a primary metric for this capacity. In Türkiye, R&D expenditures followed a mere 0.24% of GDP in the 1990s, showcasing a steady but crisis-interrupted trajectory. The long-sought 1% development target was finally surpassed in 2018 (TÜBİTAK, 2019). Driven by national structural incentives, this rate accelerated drastically to 1.40% in 2021, 1.42% in 2023, and reached an anticipated 1.46% in 2024 (Anadolu Agency, 2024), with 2026 projections aiming closer to developed nations' benchmarks through public-private financing (Turkish Statistical Institute [TÜİK], 2025).

Analyzing these financial inputs requires a clear definition of technology itself, which lacks a single, universal definition due to an expansive scope that intersects economic, social, scientific, and cultural spheres. Growing dynamically since the Industrial Revolution, it represents a vast ecosystem of accumulated knowledge, technical applications, and systemic innovation processes rather than mere machinery. In the academic literature, Dunning conceptualizes technology as vital information used to optimize production efficiency and market expansion (Tiryakioğlu, 2011: 171). Because information forms the baseline of human tools, technology is intrinsically bound to economic growth, structural industrialization, and urbanization (Hamitoğulları et al., 1974: 5). Grounding this view, Basalla defines technology as an evolutionary method for acquiring production knowledge and fulfilling societal needs (Basalla, 1996: 2-3), emphasizing that it comprises both tangible assets like machinery and intangible assets such as production techniques, patents, and trade secrets (Basalla, 2010: 2-3). This direct connection to manufacturing means that theoretical knowledge must be applied dynamically, making technology highly interactive with related scientific fields (Karacasulu, 2000: 11).

Socio-economic structures are profoundly reshaped by these technical advancements. Technology-producing nations maintain an international competitive edge, whereas developing systems with restricted local output become heavily reliant on external technology transfer. This gap often triggers "technological change," a broader social and cultural adjustment that can backfire if the imported methodology fails to suit local technical or economic conditions (Özilgen, 2011: 155). Effective technology management must therefore carefully audit internal infrastructure from initial selection to final execution (Daron, 2012: 266). Central to this management is the control of information as a strategic asset; as Daniel Bell notes, information is an organized, systematically shared expression derived from practical experience and rational evaluation (Şanlısoy, 2016: 2186).

Turning this systemic information into industrial power requires a country to bridge the gap between invention—the scientific creation of a new method—and innovation, which actively applies that concept to economic life (Shimula, 2010: 60). Across various types—including product, process, organizational, and marketing innovation—ideas must be structured into scalable projects. The eventual usability of these outputs measures authentic technological development. Ultimately, countries that fail to build a comprehensive national innovation system or sustain high-tech production capacity inevitably remain trapped in a continuous, vulnerable cycle of external technology transfer dependency (Soyak, 2008: 59).

Human Capital and Researcher Capacity

Human capital is the cornerstone of technological progress, driving structural change and

enabling nations to achieve sovereign technological autonomy (Koyuncu et al., 2022). Aligning this skilled workforce with the National Technology Initiative mitigates dependence on foreign expertise and fosters indigenous innovation (Ibrahimcioglu, 2022). This structural transformation is highly evident in defense and high-tech industries, where institutional reforms have successfully catalyzed production-driven growth (Aydin, 2025; Kacir, 2022). Empirically, incentivizing highly skilled human capital over mere physical capital accumulation yields greater returns for endogenous growth and total factor productivity (Akad & Deger, 2023), reflecting an innovation policy framework that maximizes input-output efficiency (Belgin, 2025).

As a result of these strategic policies, Türkiye's R&D workforce has experienced remarkable quantitative growth, expanding from 13,951 full-time equivalent (FTE) personnel in 1990 to 172,119 in 2018. According to recent Turkish Statistical Institute (TUIK) data, this number reached 291,000 in 2023 and exceeded 310,000 in 2024. Driven by higher education expansion, technoparks, and targeted incentives, this growth demonstrates that R&D has successfully integrated into private sector corporate culture, positioning the nation as a credible partner in high-stakes technological domains (Kacir, 2025).

Quantitative expansion alone, however, cannot guarantee long-term innovation dominance. To fully translate these physical and financial investments into global competitive advantages, Türkiye must systematically elevate project quality while expanding its international patent and publication footprint (Uner et al., 2026). Disrupting this institutional momentum is the critical threat of brain drain, where highly educated talent and specialized researchers steadily migrate to international markets—a structural exodus that severely threatens to deplete the domestic research pipeline (Abbasov, 2025; Adsiz, 2025). Empirical evidence shows that this innovation exodus significantly impedes domestic technological progress by hollowing out the localized talent pool (Mike et al., 2025). Ultimately, to achieve true technological independence, policymakers must establish advanced laboratories and design institutional mechanisms that align macroeconomic incentives with the professional aspirations of specialized researchers to retain elite human resources within the country (Akyildiz et al., 2025).

Patent Applications and Industrial Property Outputs

As the human capital pool expands, one of the most tangible and measurable macro-outputs of a country's or business's innovation capacity and technological advancement level is industrial property rights. In the literature, the success of technology management at the micro and macro levels is measured by the registration and protection of the theoretical knowledge produced, and then its transformation into economic added value (Dizdar, 2019: 7). Accordingly, industrial property indicators such as patents, utility models, and industrial designs are considered as fundamental parameters revealing the qualitative return on investment in R&D activities. In the global competitive environment, firms' ability to maintain their market share and achieve a sustainable competitive advantage depends on legally securing the unique technologies they develop. Patenting inventions resulting from R&D operations carried out within businesses not only prevents the imitation of intellectual property but also opens up a direct technology transfer and revenue stream for firms through the licensing of these rights. Therefore, the increasing trend in patent applications is the clearest macroeconomic evidence that an ecosystem is transitioning from an assembly industry to a knowledge-intensive and original production model. When industrial property outputs are examined in the context of Türkiye, it is seen that a significant momentum has been achieved in the number of patent and utility model applications in the historical process, especially according to the data of the Turkish Patent and Trademark Office (TÜRKPATENT) (Öğüt, 2012: 14). However, the main structural problem that needs to be solved in terms of the macro dynamics of national technology management is that the rate of commercialization and transformation of these quantitatively increasing patent applications into

high-tech production is still low. In line with the 2026 projections and current industrial strategies; integrating registered industrial property rights into industry, increasing the effectiveness of domestic technology transfer offices, and converting patented inventions into high value-added export products have become the priority goal of the national innovation system.

Technology Management Process

The concept of technology management strengthens management within the framework of the R&D concept and also contributes to the inclusion of new areas within the scope of management (Öğüt, 2012: 14).

The first step of the process is the analysis of existing structural gaps and the accurate identification of critical technology areas needed accordingly. At this stage, the technological capital of the actors and internal and external environmental factors (SWOT analysis) are examined to select the most suitable technology model for the targeted sectoral matrix. In the following process, the gaps between the existing capability limits and the requirements of the target market are analyzed, and capacity building strategies are implemented (Taşkın et al., 2003: 49).

In an economic context, the ultimate success of technology management is measured by the commercialization phase. The level of technological readiness puts the effectiveness behind the technology into practice and supports its development. Protecting a developed innovation with a patent and bringing it to market transforms intangible knowledge into tangible capital. Adapting the transferred elements to the structure of the receiving country increases efficiency, but conditions should be determined and adapted for both countries before technology transfer takes place (Daron, 2012: 266).

Structures that can establish their own intellectual capital create original knowledge and break external dependence. Although technology transfer is a leverage in the short term, the main goal in the long-term vision is the construction of domestic production capacity. Synthesizing these dynamics, the macro analyses on technological systems and operational mechanisms clearly delineate the conceptual boundaries of technology transfer, placing it at the very center of global economic relations and national industrial policies. Because the correct implementation of technological management, both at the firm and national levels, ensures an effective result (Campton, 1999: 55).

Technology Transfer And Its Process

In an era defined by rapid innovation and heightened global competition, technology transfer has emerged as a primary lever for economic catch-up. For developing nations, it offers a functional shortcut to expand industrial capacity, modernize manufacturing, and narrow historical development gaps. By absorbing methodologies pioneered in advanced economies, recipient nations can theoretically upgrade not just their physical machinery, but their baseline organizational workflows, technical literacy, and managerial frameworks.

However, genuine technology transfer extends far beyond the transactional import of advanced hardware. A complete lifecycle requires a sequential progression: successful acquisition must lead to local adaptation, targeted development, and eventual domestic dissemination. The efficacy of this cycle depends entirely on a country's internal readiness. Without an established economic infrastructure, a highly skilled workforce, and a receptive industrial ecosystem, imported tech fails to take root. Instead of fostering independence,

unassimilated technology transfer risks locking developing economies into a chronic cycle of foreign technological and structural dependency.

This section unpacks the theoretical definitions, sequential stages, and operational methods that govern how technology moves across borders. By evaluating these mechanics through the lens of developing market dynamics, the analysis explores Türkiye's specific position within the global innovation landscape, examining the structural bottlenecks and policy misalignments that continue to complicate its transition from a technology consumer to a technology creator.

The Concept of Technology Transfer

While early economic literature frames technology transfer strictly as a mechanism for developing nations to close productivity gaps (Akdemir, 1991: 179; Malatyali, 2016: 2), contemporary trade reveals a more complex reality. High-volume technical exchanges occur just as intensely between developed nations and major corporations, proving that technology functions as a strategic currency of global competitiveness rather than a simple remedy for underdevelopment (Tiryakioğlu, 2011: 176). Ever since the Industrial Revolution tied mechanization to economic and military sovereignty, lagging nations have relied on these cross-border flows to bypass prolonged development timelines (Şahin, 2011, p. 6).

Defining this process requires moving past basic commercial procurement. KOSGEB and global researchers view true technology transfer as a systematic exchange of operational methodologies that allows proprietary designs to be effectively commercialized by another entity (Şahin, 2011, p. 6). United Nations frameworks break this process down into four pillars: physical equipment, communication networks, localized design processes, and human capital (as cited in Dizdar, 2019, p. 10).

As Karacasulu and Demir argue, successful transfer is an active process of technological learning; it spans from initial global scanning to local adaptation, targeted development, and industry-wide dissemination (Çeştepe et al., 2006, pp. 3–4; Demir, 1986, p. 25). This sequence demands deep structural modernization and societal readiness to absorb incoming technical innovations (Kurtulmuş, 2001, p. 18). Ultimately, if used merely as a revolving door for foreign hardware without building local R&D infrastructure, it creates permanent external dependency instead of authentic domestic capacity.

Stages of the Technology Transfer Process

Technology transfer is not simply a process of transferring technology from one country or firm to another. Technology transfer has a complex structure consisting of many stages such as adaptation, assimilation, application, development, and dissemination. Therefore, the technology transfer process is carried out within the framework of specific methods and plans (Tiryakioğlu, 2011: 178). In the literature, the technology transfer process generally consists of acquisition-adoption, assimilation-adaptation, development, and dissemination stages (Karacasulu, 2000: 1).

The Acquisition Stage of the Technology Transfer Process

The first stage of the technology transfer process is the acquisition and adoption process. In this stage, learning the knowledge and skills related to the use of the transferred technology is important. For technology transfer to be considered successful, it is not enough to simply purchase the transferred technology; it must also be internalized, applied, and made reproducible. This situation necessitates a certain level of assimilation capacity (Altay, 2004: 25).

For firms, the first stage of the technology transfer process begins with identifying the technology they need and planning in which areas they will use this technology. Choosing the right technology to be transferred is one of the most important elements of the process. Because

technology transfer costs are quite high for developing countries. Therefore, it is necessary to analyze the technology planned to be transferred in detail and evaluate whether it is suitable for the country's conditions (Karacasulu, 2000: 1-3).

In the technology acquisition process, countries consider not only economic factors but also environmental, social, and technological impacts. Factors such as the adaptation cost of the technology, the payback period, its contribution to employment, its environmental impacts, its productivity level, and its sustainability play an important role in technology selection (Kiper, 2004: 62-63).

The Adaptation Stage of the Technology Transfer Process

The second stage of the technology transfer process is the adaptation stage. It is often not possible for technologies produced in developed countries to directly adapt to the economic and social conditions of developing countries. Therefore, the transferred technology needs to be adapted to the existing conditions of the country. Otherwise, the transferred technology can reduce production efficiency and increase economic costs (Ansal, 2004: 47-48).

Having expert personnel with technical knowledge is of great importance for the adaptation of the technology. Especially in developing countries, due to the inadequacy of technological infrastructure, technology transfer is often carried out with technical expertise and engineering support. This situation causes an increase in technology transfer costs (Kiper, 2004: 112). In addition, the fact that the firms producing the technology are often in a monopolistic position leads to high costs in the transfer process (Ansal, 2004: 46).

Development Phase of the Technology Transfer Process

The third phase of the technology transfer process is the development phase. In order for the transferred technology to be used effectively, countries or firms need to have the necessary technical knowledge, skills and infrastructure. For technological development to become sustainable; This is possible through strengthening education, knowledge accumulation, investment, and research and development activities (Kılıç et al., 2011: 61).

The lack of technical knowledge in the areas where technology is transferred is considered one of the fundamental problems hindering technological development. Insufficient technical capacity prevents the development of the transferred technology and leads to continued external dependence. Therefore, developing countries need to give more importance to R&D activities and improve their technological infrastructure (Kiper, 2004: 72).

The Dissemination Stage of the Technology Transfer Process

The final stage of the technology transfer process is the dissemination stage. In order for the transferred and developed technology to be widely used within the country or within the enterprise, appropriate economic and technical conditions must be created. In particular, the capital structure, educated workforce, technical infrastructure, and the level of demand directly affect the dissemination of technology (Kiper, 2004: 72).

The dissemination of technology is an important stage in making technological development sustainable. Because integrating transferred technology into production processes nationwide, rather than using it only in specific areas, yields more effective results in terms of economic development and competitiveness.

Technology Transfer Methods

Technology transfer can be carried out through different methods. These methods are generally classified as indirect and direct technology transfer methods. Indirect technology transfer methods mainly occur through information, education, human resources, and communication; while direct technology transfer methods include practices such as foreign capital investments, licensing agreements, know-how agreements, technical assistance, joint ventures, and the purchase of machinery and equipment.

Indirect Technology Transfer Methods

Indirect technology transfer methods refer to the transfer of technological knowledge not through the direct transfer of production tools or machinery, but through means such as education, publications, media, personal contact, labor mobility, and sharing of expertise. In these methods, the transferred element is often not the production technology itself, but rather knowledge regarding the use, operation, and application of the technology.

Human resources play an important role in indirect technology transfer. The employment of foreign experts and consultants, labor mobility, overseas business trips, and participation in international fairs are considered within this scope (Karacasulu, 2001: 6). In this process, the knowledge and experience possessed by individuals become an important tool in the realization of technology transfer.

Public knowledge is also one of the indirect technology transfer methods. Professional and technical publications, conferences, training programs, courses, academic studies, symposiums, and international scientific interactions are considered within the scope of public knowledge. In this method, the information transferred is more concerned with what the product is, where and how it can be used, rather than how it is produced (Çeştepe et al., 2006: 48). It is also stated that academic and technical publications, conferences, and fairs contribute to the development of technological capacity by increasing the level of education in the country (Dizdar, 2019: 39).

Educational activities are also an important tool in indirect technology transfer. Training programs of companies, commercial trainings organized by professional associations and organizations, and programs conducted by research and educational institutions are among the methods that contribute to technology transfer (Karacasulu, 2001: 6).

Direct Technology Transfer Methods

Direct technology transfer involves formalized, institutional mechanisms such as investments, legal contracts, and physical asset acquisitions that systematically move technical capabilities across borders. Unlike unstructured knowledge spillovers, these methods rely on structured corporate or state agreements to implant specific industrial capacities into a host country.

Foreign Direct Investment (FDI) serves as a primary vehicle within this category. Driven largely by multinational corporations looking to scale their production footprints globally, FDI goes beyond injecting raw capital into developing markets; it serves as a conduit for proprietary manufacturing methodologies, advanced operational workflows, and managerial systems (Çeştepe et al., 2006: 49; Seyidoğlu, 2009: 717). While frequently utilized to upgrade local industry, the success of FDI depends heavily on domestic readiness. Without a receptive economic infrastructure and aligned national innovation policies, foreign corporate presence rarely yields deep, systemic technological assimilation (Kiper, 2004: 76-77; Şahin, 2011: 7).

On a more transactional level, patent and licensing agreements allow firms to purchase the legal right to utilize proprietary inventions, trademarks, or designs for a designated fee (Koca, 2013: 54; Şahin, 2011: 8). This is often supplemented by know-how contracts. Distinct from basic equipment manuals, know-how agreements transmit non-patented operational secrets,

technical blueprints, and end-to-end production insights, frequently incorporating specialized workforce training (Karacasulu, 2001: 2; Malatyalı, 2016: 63). Similarly, technical assistance and cooperation frameworks—often subsidized through grants or international development programs—supply critical consultancy, project design support, and expert personnel to shore up localized knowledge gaps (Seyidoğlu, 2009: 785).

Human capital mobility constitutes another direct channel. The international movement of researchers, corporate engineering poaching, and the placement of foreign consultants directly transfer tacit technical mastery between firms (Koca, 2013: 114; Şahin, 2011: 11). To anchor these assets, governments frequently utilize free zones—territories operating under distinct tax and administrative incentives. By attracting multinational manufacturing hubs to these zones, states attempt to embed advanced corporate technology within national borders (Koca, 2013: 115).

Finally, the most immediate, material approach is the direct purchase of foreign machinery and capital equipment, which instantly updates a factory's mechanical capabilities. However, this method carries inherent operational risks; if the imported machinery is poorly aligned with local industrial realities, it quickly triggers severe maintenance bottlenecks, software incompatibility, and spare part dependencies (Karacasulu, 2001: 7). This material acquisition is sometimes integrated with international subcontracting, where global firms delegate segmented, specialized phases of their production line to domestic suppliers.

Technology Transfer And Technology Policies In Türkiye

Technology transfer and technology policies in Türkiye have been shaped in line with economic development goals and have gained importance, especially with the industrialization process. In the development policies implemented since the declaration of the Republic, technology has been considered a strategic element in terms of increasing production capacity and ensuring economic independence. However, Türkiye 's lack of sufficient technological infrastructure for many years has made technology transfer one of the fundamental tools of the economic development process. Policies aimed at technology transfer in Türkiye have become more prominent, especially since the 1960s, with the planned development approach. With the establishment of the State Planning Organization, the preparation of development plans, and the commencement of TÜBİTAK's activities, an institutional structure was created in the field of science and technology. In the post-1980 period, opening-up policies, foreign capital investments, and the globalization process led to an acceleration of technology transfer. The main objective of technology transfer policies is to transfer technologies produced by developed countries to Türkiye, to increase productivity in industrial production, and to improve international competitiveness. In this process, foreign direct investment, licensing agreements, technical collaborations, R&D activities, and university-industry cooperation have been used as important tools. In particular, structures such as technoparks, technology development zones, and technology transfer offices have been established to make technology transfer more effective.

This section examines the role of technoparks in Türkiye 's science and technology policies, technological development indicators, foreign direct investment, and university-industry cooperation. In addition, the problems that Türkiye has faced in the technology transfer process are evaluated, and policies aimed at developing domestic technology production capacity are discussed.

Historical Development of Science and Technology Policies in Türkiye

In Türkiye, science and technology policies have been shaped together with economic development goals from the proclamation of the Republic to the present day. The Turkish economy has implemented different growth models after 1923, and in this process, science, technology, industrialization, and development policies have developed in an interconnected manner. According to Taymaz, when the development process of the Turkish economy is examined through gross domestic product, it is possible to talk about five basic growth periods (Taymaz, 2009: 75-79).

The first period, covering the years 1920-1950, extends from the establishment of the Republic to the end of the Second World War. Although a free market approach was adopted at the beginning of this period, due to the 1929 World Economic Depression and the political and economic conditions of the time, state-led industrialization policies came to the forefront. State-supported production structures were created in the fields of textiles, food, chemicals, and light engineering, and industrialization was seen as one of the basic tools of development (Polatoğlu, 2021).

In the second period, covering the years 1950-1960, Türkiye transitioned to a multi-party system and began to integrate more with the world economy. During this period, importance was given to infrastructure investments such as roads, ports, and energy production; however, a slowdown in the rate of economic growth was observed from the second half of the 1950s onwards. Türkiye's opening to foreign markets was one of the important developments that influenced the direction of industrial and technological policies in subsequent periods. The period between 1960 and 1980 was characterized by the adoption of planned development and import substitution industrialization policies in Türkiye. With the establishment of the State Planning Organization in 1960, economic development was placed on a planned foundation, and in 1963, TÜBİTAK (The Scientific and Technological Research Council of Türkiye) was established to support scientific research and contribute to the development of science and technology policies. These developments are considered important steps in the institutionalization of science and technology policies in Türkiye. The First Five-Year Development Plan adopted import substitution policies in line with industrialization goals. During the Second and Third Five-Year Development Plans, the importance of technology transfer in economic growth was emphasized more clearly. During this period, the State Planning Organization made regulations and plans for technology transfer, and technological development was considered a part of development policies. In the Fourth Five-Year Development Plan, in addition to technology policies, support for scientific studies gained importance, and industries focused on the production of machinery, equipment, and intermediate goods were supported. The 1980-1990 period was a time when the opening up and liberal policy approach strengthened in the Turkish economy. During this period, the goals were to increase exports, control imports, and support foreign capital inflow.

R&D and Technology Policies in Türkiye

The reduction of regulations restricting foreign investments from the second half of the 1980s onwards has been a significant development in terms of technology transfer. The "Turkish Science Policy: 1983-2003" report, prepared by TÜBİTAK and DPT during this period, is considered one of Türkiye's first science policy documents. With this report, the goals of science and technology policies were determined, special budgets were allocated to R&D expenditures, and the groundwork was laid for the establishment of the High Council for Science and Technology.

The Fifth Five-Year Development Plan aimed to increase R&D activities, develop

technology in service sectors, increase qualified human resources, strengthen the effectiveness of the High Council for Science and Technology, develop industrial capacity in advanced technology fields, and support technoparks (DPT, 1984: 151). These goals show that Türkiye began to prioritize not only technology imports but also technology development capacity in its technology policies.

The post-1990 period is the period in which science and technology policies in Türkiye gained a more institutional structure. During this period, KOSGEB (Small and Medium Enterprises Development Organization) was established with the aim of providing technical and financial support to small and medium-sized industrial enterprises. KOSGEB's support in the fields of technology, R&D, financing, market research, qualified personnel, and entrepreneurship is considered important in terms of technology transfer and domestic technology development processes (Aydemir, 2005: 102). In addition, Technology Centers were established in cooperation with KOSGEB and universities, and the legal infrastructure of technoparks was created with the Technology Development Zones Law, which came into force in 2001 (Eyyuboğlu & Aktaş, 2016).

The policies implemented since the 1990s have not been limited only to supporting scientific research, but have also focused on the development and sustainability of technology. In the Sixth Five-Year Development Plan, the goals were to increase R&D activities, support the transition to an information society, improve technology transfer decisions, and expand technoparks (DPT, 1995: 70).

In the 2000s, institutions such as TÜBİTAK and the Turkish Technology Development Foundation played significant roles in supporting technology development activities. Increasing the number of technoparks, establishing a national innovation system, and strengthening technology development capacity were among the main objectives during this period. The establishment and development of a national innovation system was explicitly targeted in the Eighth Five-Year Development Plan. Following the 2001 crisis, there was an increase in public R&D expenditures, and in 2001, the "Vision 2023" project was prepared under the leadership of TÜBİTAK and with the decision of the Science and Technology Council. This project aimed to strengthen technology development, sustainability, and science-technology strategies (TÜBİTAK, 2004: 11).

The 2010-2014 Strategic Plan, prepared by the Ministry of Science, Industry and Technology, aimed to increase Türkiye's global competitiveness, achieve structural transformation in industry and trade, develop high value-added technology products, strengthen university-industry cooperation, and increase R&D capacity (Ministry of Science, Industry and Technology, 2010: 39). The 2013-2017 Strategic Plan aimed to develop advanced technology products, increase their share in exports, and support technological transformation in industry (Ministry of Science, Industry and Technology, 2012: 10).

Generally speaking, science and technology policies in Türkiye have developed alongside economic development policies since the early years of the Republic. From the 1960s onwards, institutional steps were taken with a planned development approach; after the 1980s, technology transfer gained importance with opening up to the outside world and liberal policies; and in the 1990s and 2000s, R&D, technoparks, university-industry cooperation, and the national innovation system came to the forefront. However, it is observed that the implemented policies have not fully achieved the expected success in every period. Therefore, the fundamental problem for Türkiye is to create a sustainable science and technology policy that can transform technology transfer into domestic technology production.

Foreign Capital Investments and Technology Transfer

Foreign capital investments are considered important for developing countries due to reasons such as addressing capital shortages, facilitating technology transfer, and improving management knowledge and techniques. In Türkiye, foreign direct investment is encouraged to support economic growth, increase technological capacity, and improve international competitiveness (Bal et al., 2010: 457).

Until 1980, Türkiye implemented import substitution and protectionist economic policies, and foreign trade was largely under state control. However, the inadequacy of industrial infrastructure, capital shortages, and the need for economic development made foreign capital investments important. With the transition to liberal economic policies after 1980, regulations were made to increase foreign capital inflows, and an open economic structure was adopted (Gür, 2014: 61).

The economic reforms and foreign trade policies implemented since the 1980s have contributed to making Türkiye more attractive to foreign investors. In particular, policies aimed at ensuring economic stability have been effective in increasing foreign direct investment (Bal et al., 2010: 465).

When foreign direct investment in Türkiye is examined, it is seen that investments followed a relatively stable course between 1990 and 2001. However, after the 2001 economic crisis, there was a significant decrease in foreign capital inflows. From 2005 onwards, there was a significant increase in foreign capital investments, and investment amounts reached high levels compared to previous years. This increase continued until 2007, and investments declined again due to the impact of the 2008 global financial crisis. In the following years, foreign direct investment followed a fluctuating course. When the countries that make the most foreign direct investment in Türkiye are examined, it is seen that European countries are in a dominant position. According to YASED data, as of 2025, the Netherlands, Azerbaijan, and Italy are among the top countries investing in Türkiye. When evaluated in terms of regional distribution, it is seen that the majority of investments originate from European countries; The share of Asian, American, and African countries remains at a more limited level (YASED, 2025).

When the effects of foreign capital investments in Türkiye are evaluated in terms of technology transfer, it is seen that the investments make certain contributions to economic growth. However, there are assessments that multinational companies do not contribute to the expected level in terms of technology transfer, knowledge sharing, and R&D activities. In particular, the limited high-technology production capacity of domestic firms prevents collaborations established with foreign firms from sufficiently transforming into technology production. Therefore, for Türkiye, foreign capital investments should be evaluated not only as capital inflow but also in terms of technology transfer and the development of domestic production capacity. Supporting domestic firms operating in high-technology fields, increasing university-industry collaborations, and strengthening R&D investments are important in terms of increasing the technological gains obtained from foreign capital investments.

University-Industry Collaboration and Technoparks

University-industry collaboration serves as a primary engine for regional innovation and technological capacity. By bridging academic research with industrial execution, this mechanism allows universities to secure research funding and provide practical training grounds, while equipping commercial firms with the deep technical expertise needed to solve complex marketplace challenges (Şahin, 2011: 112). Structurally, this ecosystem relies on a tripartite framework—the "Triple Helix"—composed of universities generating knowledge, industrial firms commercializing it, and the state orchestrating financial incentives and supportive policy

tools.

Because moving raw theory directly into a commercial factory floor is rarely straightforward, intermediary structures are vital. Technology Transfer Offices (TTOs), specialized R&D centers, and technoparks act as the necessary translational links to convert academic breakthroughs into viable market goods (Kiper, 2010: 8). Beyond serving as mere real estate for startups, technoparks function as dynamic knowledge hubs designed to accelerate technology transfer, anchor regional development, and scale high-value-added manufacturing (Slim, 2006: 8-15; Yalçıntaş, 2014: 86-90). The global standard for this model traces back to the inception of Silicon Valley under Stanford University's leadership in 1951, a milestone that sparked a global wave of science and technology park development throughout the 1970s and 1980s as R&D investments became tied to national competitiveness (MÜSIAD, 2012: 136).

In Türkiye, the evolution of these ecosystems faced distinct delays compared to Western economies, historically slowed by erratic economic cycles, lagging infrastructure, and a prolonged industrialization timeline (Bezen & Balan, 2019). However, the narrative shifted rapidly after the 2000s with the passage of the Technology Development Zones Law. This legislative foundation established a structured legal framework that successfully catalyzed university-industry ties and fueled tech-driven entrepreneurship. Today, Turkish technoparks host concentrated clusters in software, defense, biotechnology, and artificial intelligence. To translate this expanding quantitative infrastructure into higher qualitative yields—specifically high-tech exports—the focus must now mature toward securing sustained R&D funding, streamlining university-industry communication channels, and cultivating elite technical talent.

Systemic Evaluation And Policy Projections

Decades of strategic shifting in Türkiye's science and technology policies have successfully established a dense institutional infrastructure (Taymaz, 2009), yet translating this quantitative expansion into high-value macroeconomic output remains a persistent challenge (Aydın, 2025). Current trade complexities underscore a critical structural bottleneck: the domestic high-tech manufacturing sector remains deeply anchored to an import-dependent assembly model rather than evolving into a self-sustaining engine of original creation (Kacı, 2025). This deficit traces back to a historical misalignment in execution. Past technology transfer channels operated predominantly as transactional hardware procurement projects (Tiryakioğlu, 2011). Consequently, local industries frequently prioritized the immediate operational utility of imported machinery over the long-term, systematic assimilation, reverse-engineering, and domestic replication of complex technologies (Karacasulu, 2000).

This systemic disconnect is visible when evaluating institutional R&D inputs against actual market outputs. While targeted national incentives have driven public-private R&D expenditures and total researcher numbers to record heights (Anadolu Agency, 2024; Boyraz, 2025), a major investment gap still separates Türkiye from elite knowledge-producing economies (Belgin, 2025). More importantly, the observed surge in domestic patent filings offers a misleading metric of innovation efficacy (Öğüt, 2012). The vast majority of these registered intellectual properties remain dormant within higher education archives, failing to bridge the gap between academic theory and private-sector commercialization (Dizdar, 2019). Because universities culturally measure success through theoretical publication volumes while corporate entities focus on low-risk, immediate production quotas, intermediate bodies like technoparks and Technology Transfer Offices (TTOs) often yield uneven industrial results (Kiper, 2010). In many instances, firms inside these specialized zones cluster around low-to-medium intensity software developments or utilize the infrastructure to leverage tax exemptions rather than conducting

deep-tech breakthrough research (Yalçıntaş, 2014).

Compounding these structural vulnerabilities are acute technical talent shortages and an ongoing, high-stakes brain drain (Akyıldız et al., 2025). Highly educated talent and specialized researchers increasingly exit the domestic research pipeline for international markets, a structural exodus that significantly hollows out the localized talent pool needed to sustain complex engineering ecosystems (Mike et al., 2025).

Breaking out of this import-heavy dependency trap requires an aggressive policy pivot from quantitative target-chasing to rigorous qualitative enforcement (Gür, 2014). Policymakers must move past basic real-estate infrastructure development and actively foster deep-tech capacity building (İbrahimcioğlu, 2022). To anchor elite human resources within the country, the state must establish advanced laboratories and design macroeconomic mechanisms that align institutional incentives with the professional aspirations of specialized scientists (Koyuncu et al., 2022). Furthermore, university-industry collaboration must be restructured through mandatory, market-driven venture frameworks that penalize stagnant intellectual property and reward the direct transformation of patented inventions into high-margin, scalable export products (Şahin, 2011). Ultimately, true technological sovereignty cannot be imported through foreign capital or physical assets; it demands a persistent, long-term policy environment dedicated to turning raw academic knowledge into authentic domestic wealth (Kacır, 2022).

Declarations

Acknowledgements: Not applicable

Authors' contributions: The individual contributions of authors to the manuscript should be specified in this section. Please use initials to refer to each author's contribution in this section.

Competing interests: The authors declare that they have no competing interests

Funding: There is not any funding.

Ethics approval and consent to participate: If your research involves human subject please specify your ethical approval and consent to participate.

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