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ISTANBUL KULTUR UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

TECHNOLOGICAL DEVELOPMENT AND ECONOMIC GROWTH IN TURKIYE

MASTER'S THESIS

Murat KOÇAK
1900003050

Department: Economics

Program: Internatıonal Economics and Finance

Supervisor: Asst. Prof. Dr. Nazlı ŞAHANOĞULLARI

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ABBREVIATIONS

EU: European Union

USA: United States of America

LDCs: Less Developed Countries

ARBIS: Researcher Information System

R&D: Research and Development

RTD: Research and Technological Development

FYDP I: First Five-Year Development Plan

SCST: Supreme Council for Science and Technology

MNCs: Multinational Corporations

FYDP IV: Fourth Five-Year Development Plan

SPO: State Planning Organization

EARN: European Academic and Research Network

EPC: Economic Planning Council

GATT: General Agreement on Tariffs and Trade

DCs: Developing Countries

GNP: Gross National Product

GDP: Gross Domestic Product

DVCs: Developed Countries

IASP: International Association of Science Parks

IBRD: International Bank for Reconstruction and Development (World Bank)

IMF: International Monetary Fund

FYDP II: Second Five-Year Development Plan

EOIS: Export-Oriented Industrialization Strategy

ISIS: Import Substitution Industrialization Strategy

SEEs: State Economic Enterprises

SMEs: Small and Medium-Sized Enterprises

NIH: National Institutes of Health

OECD: Organisation for Economic Co-operation and Development

USSR: Union of Soviet Socialist Republics

TARAL: Turkish Research Area

UCTEA: Union of Chambers of Turkish Engineers and Architects

TPI: Turkish Patent Institute

TTGV: Technology Development Foundation of Turkiye

TUBA: Turkish Academy of Sciences

TUBITAK: Scientific and Technological Research Council of Turkiye

UBTYS: National Science, Technology and Innovation Strategy

ULAKBIM: National Academic Network and Information Center

NIS: National Innovation System

FYDP III: Third Five-Year Development Plan

USAMP: University–Industry Joint Research Centers Program

WIPO: World Intellectual Property Organization

WTO: World Trade Organization

C: Century

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ÖZET

Bu tezde, teknolojik gelişme ile ekonomik büyüme arasındaki ilişkiyi Türkiye örneği üzerinden incelemektedir. Bilgi temelli ekonomiye geçiş süreciyle birlikte teknoloji, ülkelerin üretim yapısı, verimlilik düzeyi ve rekabet gücü üzerinde belirleyici bir unsur hâline gelmiştir. Çalışmada teknolojinin tanımı ve teknolojik değişim süreci ele alınmakta; klasik, neoklasik, Schumpeterci, evrimci ve kalkınma iktisadı yaklaşımları çerçevesinde teknolojinin ekonomik büyüme üzerindeki etkileri değerlendirilmektedir. Tezin teorik bölümünde teknoloji politikaları, teknoloji transferi ve ulusal yenilik sistemi kavramları incelenmiş; Amerika Birleşik Devletleri, Japonya ve Güney Kore örnekleri üzerinden başarılı teknoekonomik politika uygulamaları analiz edilmiştir. Bu kapsamda Türkiye'de 1980 öncesi ve sonrası dönemde uygulanan bilim ve teknoloji politikaları tarihsel bir perspektifle ele alınmıştır. Ampirik analiz bölümünde Türkiye'ye ait veriler kullanılarak Gayri Safi Yurt İçi Hasıla ile araştırma-geliştirme harcamaları, yüksek teknoloji ihracatı, patent başvuruları, eğitim harcamaları, doğrudan yabancı yatırımlar ve enflasyon arasındaki ilişkiler ekonometrik yöntemlerle incelenmiştir. Elde edilen bulgular, teknolojik göstergelerin ekonomik büyümeyi olumlu yönde etkilediğini ortaya koymaktadır.

Anahtar Kelimeler: Teknolojik Gelişme, Ekonomik Büyüme, Teknoloji Politikaları

ABSTRACT

This thesis examines the relationship between technological development and economic growth through the case of Türkiye. With the transition to a knowledge-based economy, technology has become a determining factor on countries' production structures, productivity levels, and competitiveness. In the study, the definition of technology and the process of technological change are addressed; within the framework of classical, neoclassical, Schumpeterian, evolutionary, and development economics approaches, the effects of technology on economic growth are evaluated. In the theoretical part of the thesis, the concepts of technology policies, technology transfer, and the national innovation system are examined; successful technoeconomic policy practices are analyzed through the examples of the United States of America, Japan, and South Korea. Within this scope, science and technology policies implemented in Türkiye in the pre-1980 and post-1980 periods are discussed from a historical perspective. In the empirical analysis section, by using data for Türkiye, the relationships between Gross Domestic Product and research and development expenditures, high-technology exports, patent applications, education expenditures, foreign direct investment, and inflation are examined using econometric methods. The findings obtained reveal that technological indicators positively affect economic growth.

Keywords: Technological Development, Economic Growth, Technology Policies

1. INTRODUCTION

The concept of technology emerged from the combination of knowledge and skills necessary for creating or producing tools and instruments to satisfy human needs. As a fundamental force, technology has been influential throughout the major turning points in human history. During prehistoric times, it played a key role in the development of basic tools and simple production instruments. In the subsequent centuries, particularly with the advent of the Industrial Revolution,

Technology brought about profound transformations in production systems and organizational structures. The Industrial Revolution, for instance, led to the emergence of mechanized production, large-scale industries, and new methods of manufacturing that completely reshaped economies and societies. These advancements marked a transition from manual, artisanal methods of production to machine-driven systems, leading to increased productivity and changes in labor dynamics. As a result, technology not only revolutionized how goods were produced but also influenced global trade, urbanization, and social structures, laying the foundation for the modern world we live in today.

With the onset of the First Industrial Revolution, agricultural societies transitioned into industrial ones, shifting the source of wealth from land to energy resources and industry. The industrialization movement, which began in England, spread rapidly across much of Europe and later to the United States. At the beginning of the 20th century, the intense competition between nations for economic dominance contributed to the outbreak of the First World War.

In the aftermath of the war, countries adopted more moderate policies aimed at recovering from the devastating impacts of the conflict, and many sought to close their economies off from external influence, focusing on internal recovery. This tendency toward economic isolationism had a negative impact on global trade, and some of the defeated nations from the First World War, fueled by a desire for revenge and economic recovery, contributed to the outbreak of the Second World War.

After World War II, the level of development became a critical factor, and countries began to be classified as developed, developing, or underdeveloped.

After 1980, the importance of the "knowledge" factor rapidly increased, making knowledge-based development essential for nations. The spread of knowledge-based development strategies on the international stage turned technological advancements driven by information into the key to growth. Today, technology plays a crucial role in various fields such as data sharing, scientific discoveries, competitive production methods, communication, and international trade. In the 21st century, a common characteristic among the world's leading developed nations is their possession of advanced technology, which is closely linked to their prosperity.

The ability of countries to advance and elevate their development levels is often tied to the level of technology they possess. In this global technology race, Turkiye, during its planned economy period, began to focus on knowledge and communication technologies, marking the start of its efforts to bridge the gap in this crucial sector.

This study focuses on the importance of technology in the development process. We will address various definitions of technology, the process of technological change, the role of technology in different economic theories, and the relationship between development and technology. We will also explore the concept of technology policy, emphasizing the tools and instruments used in such policies, along with the significance of technology transfer, methods involved, and the processes that facilitate it.

We also discuss technology policies and then analyze the role of technological policies in Turkiye's development. Through this analysis, the study will highlight how technologic development has influenced Turkiye's economic growth and technological advancement.

The ability of nations to compete effectively on the international stage is closely linked to their level of technological advancement. In the current century, technology has become a critical driver of economic development. The extent to which a country can innovate, adopt new technologies, and integrate them into its economic and industrial systems directly influences its competitiveness in the global market.

As industries and economies become increasingly dependent on technology, nations that are able to harness and develop cutting-edge technological capabilities are more likely to experience sustained growth and maintain a strong position in the global economy. In this context, technological progress is no longer just an option but a necessity for achieving long-term economic prosperity and competitiveness.

In order to establish the connection between development and technology, it is essential to first analyze the fundamental nature of technology and the manner in which technological change occurs. This requires an exploration of how technological advancements take place and how they have evolved over time, impacting various aspects of society and the economy.

In this study,we will also delve into the definition of technology, examining its various dimensions and how it influences development. Understanding the processes behind technological innovation and its role in driving progress will provide a clearer picture of the critical relationship between technological advancement and economic growth. Through this analysis, we aim to uncover how technological change serves as a catalyst for development in various sectors, from industrialization to information technology, and how it shapes.

2. LITERATURE REVİEW

2.1. The Development of Technology

Technology is defined as the application of knowledge developed to achieve specific goals in the production process. It can also be seen as the practices that aim to shape and alter the environment in which humans live. Through the use of existing knowledge, technology enables the achievement of practical objectives and facilitates the completion of various tasks. technology acts as a bridge between theoretical understanding and its practical applications, turning ideas into tangible solutions. This relationship between knowledge and practical implementation allows individuals and societies to improve their efficiency, overcome challenges, and innovate in ways that transform industries, economies, and daily life. Consequently, technology plays an essential role in advancing human capabilities, addressing needs, and fostering progress in various domains.(Alçın, 2010)

According to Veblen, technology is more than just the production process required to create objects that ease human life and fulfill its needs, a task that has been ongoing since the dawn of humanity. It is, in fact, a system of knowledge and beliefs, deeply embedded in the culture and values of society. Moreover, it reflects the distinctive characteristics of modern life, showcasing how human societies have evolved in response to both practical and intellectual demands. (Veblen, 1964)

In this sense, technology is not merely a tool for survival or convenience but a complex framework through which humans interpret their environment and advance their social, economic, and cultural development. It embodies the intellectual and ideological foundations upon which contemporary civilization is built, influencing the way individuals interact with each other, as well as how societies organize and progress. (Veblen, 1964)

Marx describes technology as follows: "Technology explains how humans interact with nature, the production processes they use to sustain their lives, and how these processes shape the formation of social relations, along with the concepts and modes of thought that arise from these relationships". According to Marx, technology is not just a means of producing goods, but a central factor in the way society is organized. It influences the structure of social relations, shaping both the material conditions of life and the ideologies that govern thought and behavior. Through the lens of technology, the relationship between humans and nature, as well as the relationship among individuals within society, is continuously transformed. This interaction between technology and society plays a crucial role in shaping not only the economic system but also the cultural and philosophical ideas that guide human actions, ultimately influencing the evolution of society as a whole. (Marx, 1997)

Technological advancements not only have a profound socio-cultural impact on society, but they also create significant effects on the economic landscape, particularly influencing production processes and organizational methods. Innovations in the economic, social, and political spheres have historically marked the beginning of new eras for humanity. Over the course of history, socio-economic development has unfolded in three distinct waves: the agricultural revolution, the industrial revolution, and the information revolution. Each of these transformative phases has reshaped the way societies function, from how goods are produced to how information is exchanged. The agricultural revolution laid the foundation for human civilization by enabling more efficient food production, while the industrial revolution radically changed the methods of manufacturing and labor. More recently, the information revolution has dramatically altered communication, business operations, and even the global economy. These technological shifts are not only milestones in human history but also pivotal moments that have reshaped societies in terms of culture, politics, and economic structure. (Toffler, 2012)

Until the late 18th century, economic life in Europe was primarily based on agriculture, small-scale crafts, and trade. However, the rapid population growth, combined with advancements in agriculture, led to a reduced demand for labor in this sector, which, in turn, caused a significant portion of the population to migrate to urban areas. This migration resulted in the formation of a ready workforce in urban industries. Simultaneously, the extensive plundering carried out by colonial powers such as England laid the groundwork for the Industrial Revolution. The Industrial Revolution, which introduced humanity to the modern world, began with the utilization of steam power and electricity. This era of technological progress eventually gave rise to the information age, driven by knowledge and information technology. The transition from an agrarian economy to one dominated by industry marked a turning point in human history. The advancements in technology and industry not only transformed economies but also altered the social fabric, reshaping cities, labor systems, and the global landscape. The Industrial Revolution was the catalyst for significant changes that would lead to the emergence of the contemporary world, making it one of the most pivotal moments in the history of civilization. (Toffler, 2012)

The surge of new inventions that accompanied the Industrial Revolution. This period marked a significant shift in the relationship between technology and economic development, as innovations such as the steam engine, mechanized production, and advances in transportation and communication radically transformed industries and societies. These technological breakthroughs not only increased productivity and efficiency but also paved the way for new industries, job opportunities, and global trade. As a result, economies that embraced and adapted to these changes experienced rapid growth, while those that did not fell behind. Over time, the continuous cycle of innovation and technological progress has played a key role in driving economic expansion, fundamentally altering the structure of markets and labor forces. Today, the link between technological development and economic prosperity remains just as critical, with ongoing advancements in areas such as digital technology, artificial intelligence, and renewable energy continuing to shape the global economy.

Technological advancements took on a new dimension after World War II, both in terms of speed and quality. The First Industrial Revolution, which began in the second half of the 18th century, continued into the second half of the 20th century. The technological developments that followed this period are commonly referred to as the Second Industrial Revolution. The key differences between the two revolutions lie in the factors that determined how production activities were carried out, namely energy, information, and communication. These factors distinguish the First and Second Industrial Revolutions from each other. (Şimşek & Akın, 2003)

The Technological Change Wave, initiated during the First Industrial Revolution, remains a continuing strategy. This wave represents the shift from human labor as the primary source of energy for production to the use of machines powered by alternative energy sources. With the introduction of the Technological Change Wave during the First Industrial Revolution, machines took over the energy supply role, while humans gained control over these machines. Originating in England, the Technological Change Wave led to two important outcomes. First, human labor was replaced by machines in manufacturing processes. Second, businesses were able to produce a vast quantity of cheap goods due to the new energy sources they developed, greatly enhancing productivity and efficiency. (Şimşek & Akın, 2003)

This transition had profound implications for the structure of economies and industries, enabling mass production and the growth of new sectors. It marked the beginning of a global shift, where machines and mechanization became central to economic progress. The advancements brought about by the First Industrial Revolution were foundational, setting the stage for the ongoing technological transformations that continue to shape modern industry and society. (Şimşek & Akın, 2003)

2.2. Approaches to the Development of Technology

2.2.1. The Basic Assumptions of Technology in Classical Economics and Technological Development

The first economists to observe the reflections of the technological factor in economic life were the Classical Economists. This section will present the views of prominent economists in the field of Classical Economics.

2.2.1.1. Technology in Adam Smith

The general economic structure during the period when Adam Smith wrote his works was characterized by the transition from feudal production relations to capitalist ones. As a result, the views of the physiocrats were largely accepted, while the mercantilist approach dominated foreign economic relations. Smith acted as an ideological spokesman for capitalists and emphasized the need to remove the barriers to the guild system, which had limited production. In contrast to the physiocrats, Smith considered the source of wealth to be human labor rather than land, arguing that when division of labor occurs, labor, production, and consequently national income would increase.

In his book The Wealth of Nations, Smith illustrates how production increases when labor is divided, using a practical example. The example is as follows:

A single person can only produce ten needles a day, each of which requires ten stages to complete. However, if ten people each handle one stage of production, the number of needles produced in a day increases to 4,800. If one person were responsible for completing all ten stages, only 100 needles could be produced. This means that the division of labor increases needle production by a factor of 48. Furthermore, specialization at a specific stage allows workers to find new ways to use the technology, which in turn leads to faster and more efficient production (Alçın, 2006)

Smith's analysis highlights how the division of labor leads to significant improvements in productivity, an idea that laid the foundation for modern economic theory. He also pointed out that specialization within production processes not only enhances efficiency but also drives innovation, fostering an environment where new methods and techniques are continuously developed. The increase in production that results from dividing tasks among workers is an essential aspect of capitalist economies, contributing to economic growth and prosperity. (Alçın, 2006)

What Smith intended to convey through this example is that during this period of changing production relations, the division of labor is a compelling factor that contributes to increased productivity. In other words, the division of labor is considered a crucial step in the formation of the technological infrastructure of the time. As production relations began to shift, the rise of technological innovation played a key role in driving these changes. The increasing number of technological advancements not only enhanced productivity but also contributed to greater profitability. (Alçın, 2006)

Smith believed that the restructuring of production relations would lead to more efficient production processes, which, in turn, would enable workers to specialize and become more skilled in specific tasks. This specialization would make production faster, more efficient, and ultimately more cost-effective. As a result, businesses could produce goods in greater quantities, reducing costs per unit and increasing profits. At the same time, the emergence of new technological inventions helped boost efficiency, creating a cycle where technological progress and improved production methods fueled one another, propelling economic growth. (Alçın, 2006)

Furthermore, the introduction of new technology created opportunities for innovation in various sectors, leading to the continuous improvement of both production methods and product quality. As technological advancements multiplied, the economies of scale enabled by the division of labor allowed industries to expand and evolve rapidly. This dynamic process of technological development, combined with the rationalization of production relations, fostered the conditions for the flourishing of capitalist economies, where greater output and higher profits became increasingly achievable. (Alçın, 2006)

2.2.1.2. Technology in David Ricardo

David Ricardo, one of the founders of the Classical Economics school, played a significant role in shaping liberal thought. Mercantilists, Physiocrats, and Adam Smith examined the sources of national output and the factors of production. However, David Ricardo focused on how national income is distributed among the factors of production and the laws that determine factor shares (Özgüven, 2005: 69).

Ricardo, who stated that the primary issue of economic policy is the determination of the laws regulating income distribution, defines capital in his work on the principles of economics and taxation as "the portion of a country's wealth used in production, consisting of the necessary food, clothing, tools, raw materials, and machinery required to enhance the structure of labor (production)" (Türkcan, 2009: 82). With the entry of industrial capitalists using machinery and wage labor into the production world, it can be said that the foundations of capitalism were solidified.

During the period in which Ricardo conducted his studies, he shifted his focus from "the rise in worker wages" to "the fall in prices and profit margins" in order to explain the changes in the production system. The decline in prices, considered as the starting point of the issue, forced a reduction in costs, and as a solution, a policy of reducing wages was pursued. What is meant by reducing wages here is the use of machines instead of human labor, i.e., technological progress. Returning to the starting point, we can conclude that the fall in prices is also a result of "capital accumulation" stemming from technological progress.

Ricardo explains this process of change within the production system as follows:

A person who invents a machine will initially gain more profit than others in the market due to the cost reduction it brings. As machine usage becomes widespread, the price of the produced good, influenced by competition, will approach the production cost of the good. While the capitalist will earn the pre-machine profit, their sole benefit is the general advantage (resulting from price reduction) as a consumer (Türkcan, 2009: 91).

2.2.1.3. Technology in Karl Marx

Karl Marx, who lived from 1813 to 1883, studied the economic and social changes brought about by industrialization. Marx's theory, particularly regarding the evolution of capitalism, made a significant impact during his time. In his theory, Marx argued that societies pass through various stages, each characterized by different social classes, and that there is a constant struggle between these classes. He claimed that after capitalism, which marked the industrial society, the next stage would be socialism. The social and political behaviors that emerge during these different stages of societal development are attributed to changes in the mode of production and technology. A transition process is created through the conflict between new factors arising from technological advancements and the old ones. The emergence of capitalism is strongly linked to technological advancements (Dura and Atik, 2002: 7).

In the Marxist perspective, the impact of technology on economic development is entirely considered within the framework of class relations. According to Marx, technology is at the core of the laws of motion of capitalism and the capitalist labor process. The labor process initially begins with the relationship between humans and nature. Humans produce in accordance with their needs, and this relationship is entirely regulated and managed by humans themselves. Accordingly, the producer plans the product and the production process in advance, and at the end of this process, by using all of their creative abilities, they create a use value. This labor process not only results in the creation of a product but also allows the worker to develop and transform themselves, their personality, and their abilities (Ansal, 2004: 43).

The tools and means of production used in the production process lead to the formation of a relationship determined by the stage of development of the labor process and production forces. There are three key factors in this labor process. The first is human action—labor directed toward a specific goal; the second is the product to be produced; and the third is the tools and means of production. Over time, the mode of production in the labor process has undergone changes, and with the development of capitalism, human creativity in production has ceased to be a potential force. This is because the goal of capitalism is not for the producer to create use values, but for the capitalist to produce exchange values that can be sold for profit in the market. In capitalism, since the amount of profit or surplus value is determined by the relative power of the parties involved in the production process, the labor process has become a site for the struggle to increase the profitability of production. As a result, capitalists not only use the most advanced technology available for production but also develop technology that can control labor. In the labor process, capital exerts control over the worker's methods of performing tasks, speed, skills, and knowledge, increasing the intensity of work in order to maximize profits and increase productivity. When workers resort to strikes, slowdowns, or other forms of unionized resistance for various reasons, the continuity of surplus value production is jeopardized. In such cases, capitalists seek to free themselves as much as possible from their dependence on labor in the production process. Marx believed that technological inventions were intentionally created to suppress or control rebellious workers. All these technological developments in the capitalist labor process also reflect class relations and contradictions within the social structure (Ansal, 2004: 44-45).

The scientific management techniques developed in the early 20th century, such as Taylorism, and the mechanical assembly lines of Fordism, reduced tasks to repeated operations within defined boundaries determined by time and motion studies, breaking the work into smaller parts. This led to mass production and the alienation of workers from their skills. Modern electronic technology has further de-skilled workers while minimizing the number of personnel required (Ansal, 2004: 44-45).

2.2.2. The Basic Assumptions of Technology in Neo-Classical Economics and Technological Development

The neoclassical approach explains production as the transformation of a set of "inputs" (capital, labor, machines, raw materials, etc.) into "outputs" (goods, services) (as cited in Ansal from Elster, 2004: 39).

In neoclassical theory, the definition of technology is closely related to the production technique. Production technique refers to the various combinations of labor and capital required for a certain amount of production. In this context, technology is considered as a production technique index in neoclassical theory (as cited in Soyak from Gomulka, 2011: 2).

Technology is seen as a physical force that transforms inputs into outputs and is represented as a production function. According to neoclassical economists, since production technology is represented by the production function, technological development can be understood as a process related to changes in the relationship between the inputs and outputs, reflected in the coefficients of the production function (Soyak, 2011: 2).

When this process is explained in terms of the two key inputs in the neoclassical production function, labor and capital, the output quantity is expressed as Q = T(S, E). According to this relationship, the Q curve represents countless techniques that have different combinations of labor and capital, yet produce the same amount of output with the same level of efficiency.

In neoclassical economic analysis, changes in "production technology" are generally focused on the analysis of the production technology of a homogeneous good or group of goods, rather than working on producing better quality new or existing goods. Technical progress, the discovery of new goods and services, and even their supply to the economy are considered outside the scope of economic analysis (Türkcan, 2009: 22).

Technological development is considered as the production of the same good with fewer inputs at the same scale, and its causes are seen as external to the economy. In other words, technological knowledge is assumed to be an external factor with a public nature. Therefore, technology is easily understandable, can be bought and sold, and its transfer from firm to firm does not require significant effort or cost. Similarly, there are no issues when transferring it from one country to another (as cited in Ansal from Elster, 2004: 39).

Moreover, firms select the most suitable input combinations and techniques from those clearly defined and become users of those techniques. As a result, since a stable and static equilibrium is assumed in the economy, firms do not make efforts to develop these techniques (Ansal, 2004: 40).

In summary, in the neoclassical approach, existing techniques are not viewed from a historical perspective, and the development of technology within the historical process and its relationship with the economy are not considered. Technological development's impact on the economy is solely seen as contributing to production by using fewer inputs, that is, an increase in productivity (Ansal, 2004: 40).

2.2.2.1. Technology in the Schumpeterian Approach

Schumpeter, his theory of technological development, explored the impact of technological and organizational changes on economic growth. He discussed how the inevitable competition generated by the capitalist system leads to innovations and the profit opportunities these innovations provide. In this context, Schumpeter analyzed capitalism as a dynamic, innovative, and evolutionary process, in contrast to the stable equilibrium presented in neoclassical theory. He argued that technological progress is the key driver of change within the capitalist system. According to Schumpeter, technology plays a crucial role in market systems built on competition. As firms in the market engage in intense competition for profits, this drives them to support technological advancements in order to increase their profitability. Technological development, backed by firms, will lead to higher profits and contribute to economic growth. In this regard, while technology is considered an external factor in neoclassical economics, Schumpeter's approach views it as an internal factor, shaped by the time and effort firms and economies invest in a competitive environment (Ardor and Varlık, 2009: 25).

According to Schumpeter, technological development is a process that evolves through invention, innovation, and diffusion, ultimately leading to "creative destruction." In other words, Schumpeter views technological development as a process brought about by innovation (Ardor and Varlık, 2009: 26).

To summarize briefly, in Schumpeter’s framework, technological innovation is a qualitative and radical change that signifies a break from existing technology, and it is not continuous. It increases production but is a broader concept than the technical innovation presented in neoclassical theory. It includes the introduction of new products, new production methods, the opening of new markets, the discovery of new raw materials, or the formation of new market structures (such as the creation or destruction of a monopoly). Through the technological innovation they introduce, entrepreneurs are able to achieve above-normal—“supernormal”—profit margins and attain a monopoly position. As this innovation is adopted by other firms over time, profits return to a normal level, and this cycle continues until another entrepreneur creates a new technological innovation. This creates business cycles within the economy. Therefore, the technological innovation emerging from the extraordinary efforts of entrepreneurs is considered an intrinsic element of the economy and is regarded as the most significant factor driving economic development dynamics (Ansal, 2004: 41).

2.2.3. The Fundamental Assumptions of Technology and Technological Development in Evolutionary Theory

In evolutionary theory, the approach to technology is focused on explaining the technological differences between firms, which is an area left unexplained by neoclassical theory (Ansal, 2004: 42).

The key distinction between the evolutionary approach and the neoclassical approach is its emphasis on the processes of "technological innovation" and "learning" in the economic development process. Within this framework, the focus is on how firms develop new technologies and adapt to technological innovations, unlike the neoclassical approach, which examines the allocation of resources in the current state (Eşiyok, 2004: 12).

In evolutionary theory, technology is not only defined as a physical process where inputs are converted into outputs but also emphasizes technological knowledge and how this knowledge is utilized within organizations. According to evolutionists, innovation is not limited to improvements and innovations related to products and production processes, but also includes new developments in areas such as management, knowledge, organization, and finance. Therefore, it is closely related to the application of economics, business, sociology, and other social sciences to industry and firms (Ansal, 2004: 42).

Since technological innovation and learning are central to the evolutionary approach, it focuses on the processes of generating, processing, storing, and transferring knowledge. In this economic approach, the knowledge bases of firms are defined as follows (Eşiyok, 2004: 12):

- They are differentiated and multi-layered, meaning they exist in various forms and levels.
- The knowledge bases specific to firms are organized by the few specialized functions within the firms.
- They are acquired through costly research, learning, and adaptation processes, and thus are path-dependent.

- They are systemic in the internal context, arising from various activities within the firm.
- When the production of knowledge results from interactions between different institutions, it is systemic in the external context.

With the increasing prominence of firms as the source of technological development, R&D activities have become even more crucial in the planned innovation process. The neoclassical approach assumes that all firms implement the same strategies, which makes it inadequate in evaluating the importance of R&D activities. However, in the evolutionary thought system, firms engage in R&D in order to sustain their existence in changing market conditions, and as a result of these efforts, technological innovation emerges (Eşiyok, 2004: 12).

According to this theory, although firms are the source of technological innovation, technological development and technological knowledge emerge within specific institutions. These institutions include universities, public-private research organizations, and firms that both use and create new knowledge in their core activities (Soyak, 2011). There are two key characteristics in the process of creating technological knowledge. One is the inherent uncertainty of the process. Since the outcomes of R&D activities aimed at creating technological innovations cannot be predicted in advance, they carry uncertainty. The other characteristic is the potential for technological knowledge, once created, to be transferred to other firms in a way that may affect the original creator's returns.

As firms in a country carry out R&D activities and create technological innovations, they not only increase their commercial success but also contribute to the country's overall welfare. After neoclassical economists who examined the impact of technological innovation on economic development at both the country and firm level, evolutionary theorists introduced an endogenous technological development approach. This approach, based on findings about the microeconomic nature of the technological development process, highlights inter-firm differences.

2.2.4. Basic Assumptions of Technology in Development Economics and Technological Progress

Finally, when discussing the role of technology in development economics, it can be observed that all developed countries in the world have highly advanced science and technology sectors. In development economics, technology is seen as an element of dependency. This is because developing countries transfer the technology they need during the industrialization process from developed countries. This situation makes the industrializing countries dependent on the core nations. Moreover, technology transfer from developed countries leads to inefficient production and income distribution imbalances in the recipient countries. Despite the scarcity of capital, technology purchased at high costs often results in unemployment while also creating a need for experts, leading to new costs (Ansal, 2004: 46).

As seen, the technologies of developed countries not only foster dependency in such nations but also cause many negative consequences. Therefore, these countries must make technology choices based on the specific conditions of their societies, and they should prioritize labor-intensive, small-scale, simple technologies that can employ their abundant and cheap labor. Alternatively, these nations should strive to develop their own scientific, technical, and skills capacities according to their social and economic conditions and create their own technologies. To achieve this, they must adopt an effective science and technology policy, making social, economic, and cultural independence, as well as self-sufficiency, their primary goal (Herrera, as cited in Ansal, 2004: 48).

2.3. Technology and Development

In this section of the study, the relationship between technology and development, as well as its importance, will be discussed.

2.3.1. The Relationship Between Development and Technology

With the Industrial Revolution, "technology" became one of the most effective tools driving development, attracting the attention of many economic thought schools, and efforts have been made to explain the relationship between development and technology. Classical, Marxist, and neoclassical economists all acknowledge that technological development is the key to achieving economic growth (Tiryakioğlu, 2011: 172). Traditional growth theory also recognizes that knowledge accumulation plays an undeniably significant role in the growth process. The major factor in sustaining capital accumulation is technological development. In the absence of technological progress, marginal productivity decreases, and per capita income begins to approach zero. The discovery of new machinery and intermediate goods leads to new investment opportunities.

In the years following the war, the acceleration of work in science and technology led to the creation of new technologies, their transfer to the market, their widespread adoption, and their continuous development within the framework of new products and production processes. These factors have been key in increasing the efficiency of certain sectors (Freeman and Soete, 2004: 363).

Since the emergence of classical economic thought, technological development has played a crucial role in all areas of development. In this context, today, technological progress has become a significant force not only in economics but also in social and cultural spheres, international competition, and productivity growth (Tiryakioğlu, 2011: 172).

2.3.2. The Importance of Technology in Development

Technological development not only creates socio-cultural impacts within society but also plays a revolutionary role in economic development and growth. The industrial revolution, known as the transition to a new era, accelerated the pace of new inventions, thus enhancing the impact of technology in the economic realm. In a capitalist economy, "competition" is undoubtedly the most important factor. In this context, the creation of new technologies is fundamental for competitiveness in international markets. Technology has evolved into a force that fully substitutes physical labor and partially replaces intellectual labor, significantly altering other production factors.

For countries to achieve development and growth, they must increase productivity in order to generate production and profits from it. This is where technology comes into play, as advanced technology translates into higher productivity. Therefore, it can be said that there is a directly proportional relationship between productivity and technology.

Economic approaches have also examined this relationship, leading to the conclusion that employment increases in correlation with productivity, and technological advancements are the primary drivers of this increase. For countries wishing to progress in economic growth and development, the key lies in technology. This is because the global economy is becoming increasingly competitive and more globalized, dominated by the growing influence of information and communication technologies.

In short, the level of technological development is one of the primary factors determining a country's position in the world and enabling it to gain a competitive advantage in the international arena.

3. DEVELOPMENT and TECHNOECONOMIC POLICIES

The role of science and technology in the growth and economic development of countries is rapidly increasing. As science and technology become effective tools for achieving success, the need for technoeconomic policies emerges in order to maintain a stable approach and demonstrate a consistent improvement in productivity in this field.

3.1. Technoeconomic Policy

In order to achieve the benefits that technology can provide through transfer or production, it is necessary to proceed systematically and outline a clear roadmap. This section will focus on the definitions of technoeconomic policy, the reasons why these policies are needed, and the tools used to implement them.

3.1.1. What is Technology Policy?

Technology policies can be defined as directing scientific and technological efforts to meet the economic, social, political, and military needs of a country and to achieve the goals set for addressing these needs (Özdaş, 2000: 11).

In other words, it refers to a set of policies that involve government intervention in the economy to influence the process of technological change (Taymaz, 1993: 550).

Finally, Türkcan defines Science and Technology Policy as a comprehensive set of policies created through scientific, social, and political analyses, which considers both internal and external factors of science and technology systems and their interactions with other societal systems (Türkcan, 2009: 203).

These policies can be applied at both micro levels, such as individual firms and organizations, as well as in broader sectoral areas or at the macro level, which involves the entire national economy, society, and even international relations (Türkcan, 2009: 204).

Science and Technology Policies aim to enhance a country's Research and Development (R&D) capabilities and thus improve proficiency in producing science and technology. Additionally, these policies focus on acquiring the ability to convert new scientific and technological findings resulting from R&D activities—essentially, the produced science and technology—into economic and social benefits. Developing this capability is the main framework of these policies (Göker, 2000: 2).

In short, the focus of Science and Technology Policies is on development, which includes economic growth and improving the quality of life. The most effective tool for achieving this goal is technology.

For countries to structure their development policies in a systematic and continuous way, technology policies must be designed in accordance with their requirements, technological research must be conducted, and these technological advancements must be transferred to industry. In capitalist economies, market signals are among the key factors influencing the technological development process. Therefore, it is impossible to consider technology policies independently of industrial policies. In countries aiming for industrialization, technological change and development can be achieved.

Looking at the historical development of technology policies, we observe that after World War II, the focus was on political and national security objectives, with basic sciences as the tools. However, as we move towards the present, innovations have become the tools used to aim for higher living standards.

Table 1. The Historical Development of Science and Technology Policy

		TOOL		
		Basic Sciences	**Core Technologies**	**Innovations**
PURPOSE	**Social Employment and Quality of Life**			
	Economic Competition in a Second			
	Political (National Security)			

Source: Turkish Academy of Sciences. From the Past to the Future: Turkish Science and Technology Policies. Ankara. Turkish Academy of Sciences Publications: 2004, p. 68.

3.1.2. Why is Technology Policy Necessary?

Countries need to implement science and technology policies as tools to achieve economic, social, and political objectives and to gain a competitive edge in international markets. The need for such policies stems from what is referred to as market failure. Market failure occurs when the economic activities conducted by firms involved in R&D do not yield benefits that can be fully appropriated by the economic unit involved, either due to a lack of conditions that allow for appropriating the results or because of the risks carried by the ventures. There are three sources of market failure. The first is the relationship between the creator and the user of technological knowledge. A user must have sufficient information about the technology they acquire, otherwise, it can be very difficult to establish a market for technological knowledge. The second source is the conflict between social and private costs and benefits. According to the public good argument, once knowledge is created, it should spread rapidly to maximize the social benefit derived from its use. However, in this case, economic units that do not bear the cost of creating the knowledge can also benefit, creating a free-rider problem. This situation can lead to insufficient investments in technological development due to market inadequacies. Third, the process of creating technology involves uncertainty, as the commercial and technical returns cannot be easily predicted. This uncertainty leads to significant problems in financing R&D investments in developing countries. As a result, market inadequacies are observed in the technological development process, and it is argued that these problems can only be solved by improving market mechanisms. In order to enhance the functioning of markets, government intervention in science and technology policies is suggested (Soyak, 2011: 34-38).

Techno-economic policies can be classified under different categories depending on the stage of the innovation process. In this context, the first group of policies focuses on expanding the scientific system for scientific discoveries, supporting basic research, and promoting educational activities. The second group supports R&D activities, which are crucial inputs for the technological innovation process. The third stage involves policies aimed at disseminating technological innovations, while the fourth focuses on policies to create demand within the framework of existing technologies (Alçın, 2010: 106).

3.1.3. Tools of Technology Policy

When considering technology policy as a set of instruments used by the government to encourage, guide, and manage activities aimed at acquiring technological capabilities, government intervention methods emerge as tools of technology policy. The government intervenes in policies designed for the country's development using these technology policy instruments. Table 2 classifies the tools of technology policy (Taymaz, 1993: 559).

Industrial policies are distinct from macroeconomic policies since they target specific sub-sectors of the economy. While macroeconomic policy tools such as tax rates, public spending, and interest rates generally do not make distinctions between firms or industries, industrial and technology policy instruments such as R&D subsidies, tax incentives, favorable loans, and credit allocations are aimed at specific firms or sectors. Other components that make up industrial policy include competition policy, investment policy, regional development policies, and technology policy. Therefore, technology policy is considered an important component of industrial policy (Soyak, 2011: 149).

Science and technology policies are implemented in the form of "mission-oriented policies" to take international strategic leadership, "technological diffusion policies" aimed at enhancing the ability of the industrial structure to adapt to technological change, and "policies for achieving national technological goals" aligned with these technological diffusion policies. When using technology policy instruments, two important points must be considered: identifying which stage of the technological change process the instrument targets, and determining the specific issue to be addressed (Taymaz, 1993: 559).

The technology policy instruments presented in Table 2 are analyzed under two main categories: financial and non-financial instruments.

Table 2. Classification of Technology Policy Instruments

Relationship with the Market ↓	Types of Instruments →	Financial Instruments	Non-Financial Instruments
Provision of goods and services by the public sector		*Supporting the exchange of R&D personnel between the public and private sectors	*Policies supporting the diffusion of technology *Human resources development policy *University and government R&D activities *Industrial standards
Modification of market incentives		*Tax incentives for R&D *Providing direct funding for R&D projects in the form of grants with their own guarantee *Promotion of national R&D projects *Implementation of joint cooperative R&D projects between the government and the private sector	*Purchases related to the defense industry *Intellectual and industrial property regime
Supporting the development of the market mechanism		*Creation and development of specialized financial market structures such as venture capital	

Source: Alkan Soyak. Teknoekonomi**.** Istanbul, Der Publications: 2011, p. 153.

In Table 2, non-financial instruments are classified as industrial property rights and patent protection, while financial instruments are categorized as monetary support for R&D. In developing countries, the function and benefits of policy tools, such as the protection of industrial property rights and support for R&D activities, should be addressed within the framework of long-term technology policies, taking into account the country's level of industrialization and technological advancement (Soyak, 2011: 154).

Various tools can be used in technology policy. These can be grouped into five categories: National Innovation System, Regional Innovation System, Technopolis-

Technopark Applications, R&D Supports, and Industrial and Intellectual Property Rights.

3.2. The Concept of Technology Transfer and Technology Transfer Methods

3.2.1. What is Technology Transfer?

Technology transfer has been considered the most important tool for acquiring technology in the development strategies of countries over the past 100 years. After the Industrial Revolution, in the 19th century, the United States and some European countries increased their efforts in technology, replacing human labor with machines in production, and built up their technological capabilities to a certain level. With the realization that technology played a significant role in political, military, and economic power during the wars of the 20th century, activities in this field increased, accelerating its development. All these developments led countries to focus on the process of "Technology Transfer," which involves not only producing technology but also ensuring its utilization and sharing in various ways.

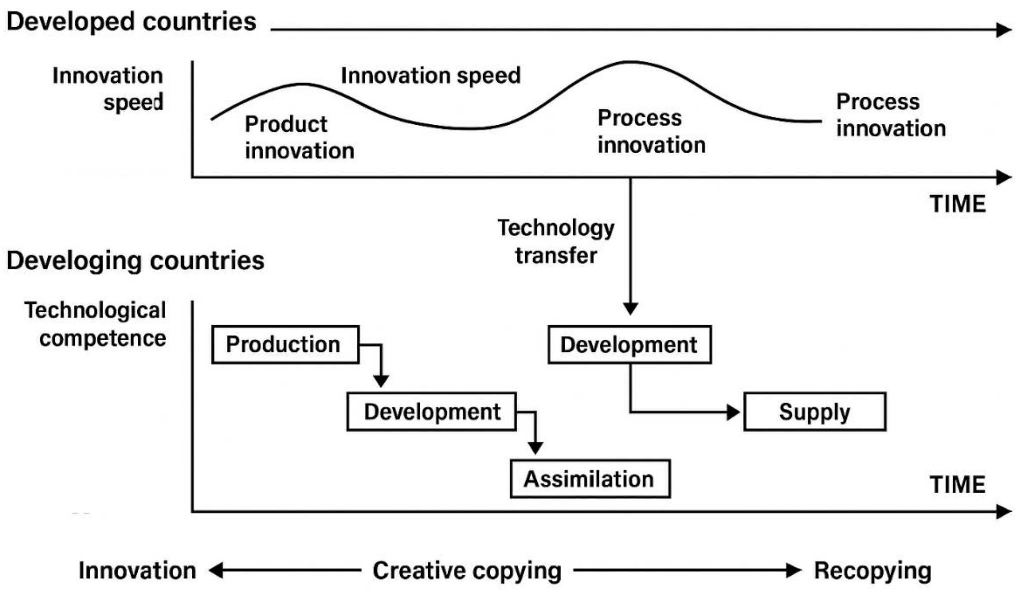
To define technology transfer, it can be described as the import of technologies that are of mutual interest, and it is a systematic approach required for manufacturing products, implementing processes, and delivering services (Ayhan, 2002: 213-214).

International technology transfer refers to the transfer of new technologies or technological knowledge from the country where they are developed to other countries around the world.

Countries that engage in technology transfer are typically those that are lagging behind in industrialization and require technology for their development and growth. For these countries, the most effective method of acquiring technology is through "technology transfer" (Kaya, 2006: 1).

Developed countries also engage in technology transfer not only to support less developed or developing nations but also to enhance their own productivity, drive economic growth, and promote development. While the primary objective for the exporting party is profitability, the importing side views technology acquisition as a means to foster development and strengthen its competitive advantage (Tiryakioğlu, 10).

For developed countries, the impact of technology manifests in innovation curves for products and processes over time. In contrast, for less developed nations, technological competence evolves along the time axis, reflecting the progression from transferred technologies to higher levels of development. When this transformation is mapped, it can almost give the impression of time being rewound, as the development path of less developed nations mirrors past technological advancements of developed countries (Kiper, 2004: 62).



Source: Kiper, 2004: 62

Figure 1. Technology Projection

Source: Mahmut Kiper, *Technology Transfer Mechanisms and University-Industry Collaboration in This Context*, p. 62, 2004.

In Figure 1, the transfer of technology from developed to less developed countries may appear to create a repetitive cycle on both ends, seemingly rewinding time and illustrating technological evolution as a linear process. However, the core message is that the country transferring technology must carefully select the most suitable technology based on its circumstances and implement it using the appropriate method at the right time. To ensure that technology transfer is effective and contributes to national development, it is essential to establish a solid infrastructure through national science and technology policies and to disseminate the technology widely using appropriate strategies.

In this regard, countries follow specific criteria when acquiring technology (Kiper, 2004: 62). These criteria can be summarized as follows:

- Environmental Impact: This category considers global, national, and regional effects, including emission levels, the cost of waste rehabilitation, and social acceptance.
- Technological Impact: This includes the maturity of the technology, its level of innovation and advancement, its reliability, the extent of its application, and its usability and accessibility for widespread adoption.
- Economic Impact: This refers to the contribution of the technology to a company's cost structure, pricing strategies, and financial policies, as well as factors like payback periods, adaptation expenses, and sustainability costs.
- Social Impact: This involves social efficiency, improvements in human capital quality, contributions to other industries and sectors, and the technology's effects on employment and income distribution.

Beyond these criteria, for technology transfer to be successful, collaboration between the public sector, universities, and industry must be established. Additionally, the know-how associated with the technology must also be transferred to ensure that recipient countries can operate, maintain, and repair the technology. In this context, the tangible aspect of technology transfer consists of physical equipment, while the intangible aspect refers to the accumulated knowledge and expertise, known as know-how.

Technology transfer does not always require the technology to reach full maturity. In some cases, during the innovation phase, technology can be developed and disseminated simultaneously through an innovation-network model. A technology transfer is considered complete when the knowledge and skills acquired through the transfer are internalized and lead to the reproduction and further development of the technology (Kılıç and Ayvaz, 2011: 61).

To sum up the primary goal of technology transfer is to enhance economic growth and development by improving technical expertise, managerial knowledge, and operational capabilities, thereby increasing competitiveness, productivity, and efficiency (Kaya, 2006: 1).

3.2.2. Technology Transfer Methods

Technology transfer can be broadly defined as a dynamic process that involves the exchange of knowledge, experience, and equipment among various stakeholders, including governments, companies, research and development institutions, financial organizations, and non-governmental organizations. As a result of the direct and indirect interactions established among these stakeholders, different technology transfer methods emerge. The most commonly used technology transfer methods include the following (Kiper, 2004: 74):

- Direct purchase
- Licensing and know-how agreements
- Turnkey facility investments
- Supply chain relationships
- Joint ventures
- Foreign direct investments (FDI)
- Collaborative research agreements and production partnerships
- Export of products and capital goods
- Franchising
- Exchange programs for scientific and technical personnel
- Consulting services and employment of foreign experts
- Education and training programs
- Science and technology conferences, fairs, trade promotions, and personal networks
- Business visits
- Company acquisitions
- Open literature (such as periodicals, books, articles, etc.)
- International credit and aid programs
- Government support programs
- R&D and university-industry collaborations

If technology transfer is defined as the process of transferring processed knowledge from one party to another, it can be categorized into two main approaches based on the nature of the transfer and the level of mastery over the transferred knowledge: Vertical technology transfer methods and horizontal technology transfer methods.

4. TECHNOECONOMIC POLICIES IN THE WORLD and IN TURKIYE

4.1. Technoeconomic Policies with Country Examples

In this section, we will explore the strategies of successful countries that recognized early on the significant impact of science and technology on economic development. We will examine what these countries have done so far in this field and how they have implemented their approaches.

4.1.1. The Example of the USA

The United States has long held a leading position globally in the fields of science and technology. In shaping its short- and long-term science and technology policies, it takes into account the country's unique social, cultural, and economic dynamics (Ayhan, 2002: 314).

Among the countries excelling in technology transfer, the USA stands out as a prominent example. One of the key factors behind this success is the establishment of the National Technology Transfer Center in 1989. Backed by federal funding, this initiative provided support to research laboratories and facilitated the transition of newly developed technologies to the private sector. Several institutions in the U.S. play a significant role in transferring technology to private enterprises. These include research centers supported by the National Science Foundation (NSF), the National Institutes of Health (NIH), universities, other federal research organizations, and NASA. Additionally, collaborative R&D consortia between firms have also contributed to this process. Since the 1980s, the U.S. has promoted university-industry partnerships, particularly to support small enterprises. More than a hundred research centers were established in collaboration with universities, of which 55 are still operational today. These initiatives have resulted in noteworthy achievements in technology transfer (Ayhan, 2002: 216).

To support the implementation of technology transfer initiatives, two significant legislative acts were introduced in the United States in 1980. The first, the *Technology Innovation Act,* mandated all federal laboratories to adopt technology transfer as a core mission. This law also led to the creation of *Offices of Research and Technology Applications (ORTAs)* to ensure this mission was effectively carried out. The second, the *Patent and Trademark Amendments Act*—commonly known as the Bayh-Dole Act—was enacted to enable universities and other research institutions to gain greater control over inventions and innovations resulting from federally funded research. It also allowed individual researchers to share in the commercial benefits of their discoveries (Guston, as cited in Ayhan, 2002: 217).

These legislative changes, especially in the area of patent rights, significantly boosted the number of patentable inventions in universities, particularly in fields such as molecular biology, solid-state physics, and computer science. As a result, many faculty members became involved in science-based entrepreneurship, establishing companies grounded in their academic research (Etzkowitz, as cited in Ayhan, 2002: 217).

By the early 1990s, as part of a broader technology transfer policy agenda, universities began establishing *Technology Licensing Offices* and *Venture Capital Offices*. These were aimed at encouraging faculty to pursue patents and assisting with related administrative procedures. In this context, numerous start-ups emerged through university channels, and efforts to transfer technologies to industry gained momentum.

A key reason behind the United States' success in this domain has been the strong alignment and commitment of universities, the public, and industry to the implementation of these policies.

When Bill Clinton assumed the presidency in 1993, his administration placed even greater emphasis on science and technology, intensifying efforts and investments in these areas.

As part of these ongoing efforts, the United States identified key priority areas in science and technology policy to support technological advancement (Yücel, 1997: 59). These focus areas included:

- Fostering a national culture and mindset centered around science and technology,
- Developing advanced supercomputing infrastructure and national computer networks,
- Strengthening education in mathematics and the sciences,
- Advancing materials technology,
- Promoting biotechnological innovation,

- Enhancing advanced manufacturing methods.

Following the identification of these strategic priorities, the Federal Coordinating Council for Science, Engineering, and Technology promptly initiated efforts to develop and implement corresponding programs. Within this framework, both public and private sectors in the U.S. pursued scientific and technological research, albeit with differing goals. The private sector concentrated on technology development driven by commercial interests, while the public sector, under the guidance of federal agencies, directed its focus toward foundational scientific research. This included targeted investments in key areas such as defense, health, energy, and space—sectors considered national priorities.

Thanks to the active involvement of universities, private enterprises, and industrial institutions—combined with effective federal technology policies—the United States emerged as one of the world's leading centers for technological innovation and production.

4.1.2. The Example of Japan

Japan's science and technology policies have roots stretching back to the 19th century. During this period, nearly 50,000 primary schools known as *terakoya* operated with a special educational status. A major turning point came in 1886 with the *Meiji Restoration*, which introduced reforms making elementary education compulsory. This foundational push in education laid the groundwork for Japan's future technological advancement. The national motto "Eastern ethics, Western technology" emerged from this period, reflecting Japan's intent to blend cultural values with technological modernization. The momentum generated by these early initiatives contributed significantly to industrial policy developments prior to World War I (Ayhan, 2002: 322).

Between the two World Wars, Japan made notable progress in its chemical industry and achieved global standards in heavy industry. The country adopted a strategy of importing technology, while simultaneously investing in human capital, education, and R&D—elements that enabled Japan to rapidly enhance its technological capabilities. In addition, the government played a pivotal role in supporting large family-run conglomerates, which contributed to the accumulation of capital and industrial growth (Alçın, 2010: 129).

Following World War II, Japan emerged as one of the most successful examples of policies inspired by Listian economic thought. Despite experiencing catastrophic destruction—losing many civilians and soldiers, and suffering extensive damage to ports, railways, power plants, and natural resources, while also seeing its prewar trade relations collapse—Japan began to rebuild amid a dramatically shifting global socio-economic landscape (Siso, 2008: 69).

The United States provided substantial military-related financial support during the post-war years, aiding Japan in its recovery. However, Japan's true resurgence was driven by internal strategies aimed at restoring national strength. Key cultural and social characteristics—such as collective solidarity, an emphasis on consensus, a guardianship-based governance style, and a strong drive for achievement—played a decisive role in this process (Siso, 2008: 69).

In the years following the war, Japan focused heavily on the steel and automotive industries, transitioning to large-scale mass production. It also became one of the first nations to implement *Quality Circles*, a system that would become central to technological innovation. To shield emerging domestic industries from international competition, Japan promoted protectionist policies, including the widespread use of the slogan "Buy Japanese."

By the 1950s, the production of advanced technological materials had become a major component of national science and technology policy. The country's engagement with the electric vehicle sector began in the form of assembly-based production. Mechanisms were introduced to accelerate technology imports, paving the way for Japan's independent innovation efforts in the latter half of the 20th century.

In the mid-1960s, Japan began removing protective measures that had previously shielded its imports. This shift opened domestic industries to global competition and significantly boosted their international competitiveness. Following the global energy crisis in 1973, Japan prioritized resolving its energy challenges and began actively seeking alternative energy sources. By the 1980s, Japan had advanced to a level where its technological production began to rival that of the United States (Ayhan, 2002: 323). During this period, Japan increased its global share of automobile manufacturing from just 1% to an impressive 23%. Meanwhile, Japanese shipyards began producing more than half of the world's commercial vessels.

A key factor underlying Japan's remarkable technological rise was its substantial investment in research and development. Allocating approximately 3% of its Gross Domestic Product to R&D and intensifying its focus on innovation, Japan soon ranked second in the world in terms of patent output, just behind the United States.

In 1996, the "Basic Law and Plan for Science and Technology" was enacted. This legislation outlined a new national strategy aimed at enhancing scientific creativity and elevating Japan to a global leadership position in science and technology. The strategy emphasized research and development in foundational technologies expected to shape the future, and identified key priority areas:

- Superconductors,
- Advanced materials,
- Biotechnology,
- New electronic materials,
- Software development.

That same year, Japan's public spending on research and development grew by 6.9%, reaching $26.7 billion—the highest figure since 1979. In Japan, roughly one-quarter of R&D funding originates from the public sector, while the remaining three-quarters are financed by private industry (Yücel, 1997: 60).

Similar to other technologically advanced nations, Japan has successfully established a strong collaboration between the private sector, public institutions, and universities. These sectors have collectively embraced national technology policies and contributed through dedicated and innovative efforts, consistently elevating the country's technological trajectory.

Today, Japan boasts around 700,000 researchers, the majority of whom are engineers. The country places significant emphasis on the education and training of these professionals. In terms of both R&D investment and the number of individuals employed in the field, Japan ranks second globally, following only the United States (Ayhan, 2002: 325).

4.1.3. The Example of South Korea

Between 1910 and 1945, Korea functioned essentially as a colony of Japan, during which time a significant portion of its industrial facilities were owned and operated by the Japanese. After gaining independence in 1945, the country was divided into South and North Korea. This separation also led to a division of the economy—agriculture and textile production were concentrated in the South, while industrial infrastructure remained largely in the North. However, during the Korean War that began in 1950 between South Korea and the Chinese-backed North, South Korea suffered significant human and infrastructural losses, including much of its production facilities (Ayhan, 2002: 326).

Following the war, South Korea embarked on a rigorous recovery process. By the 1960s, development plans emphasizing science and technology began to take shape, which bore similarities to the contemporary strategies adopted in Turkiye. Broadly, South Korea pursued a developmental path aligned with Listian principles, drawing heavily on Japan's experience as a structural model. The nation’s strategic objective extended beyond catching up with global technology—it aimed to take the lead in emerging strategic technologies. Echoing List’s formulation, this strategy emphasized acquiring existing technologies, innovating upon them, and developing the capacity to reproduce them at a higher level.

South Korea’s approach to development was comprehensive, integrating science and technology policies with industrial, educational, and research strategies in alignment with its national vision (Göker, 2000: 10). Because the strategy was long-term in nature, it necessitated a strong and consistent state role. Accordingly, the state assumed a central coordinating function, mobilizing all national resources, and playing a crucial role in the country’s industrial transformation (Göker, 1993: 10).

During the post-1960 period of rapid development, South Korea began replicating imported goods and disseminating the acquired know-how domestically. To meet the growing research needs of its industrial sector, the government established the Korea Institute of Science and Technology (KIST) in 1966. In the 1970s, industrialization efforts focused on the heavy industry sector. As the industrial base matured into the 1980s and became capable of conducting its own R&D, KIST redirected its focus toward long-term research and, in 1981, merged with the Korea

Advanced Institute of Science (KAIS). This merger led to the establishment of the Korea Advanced Institute of Science and Technology (KAIST), with the goal of creating an environment conducive to attracting Korean scientists from abroad and retaining domestic talent. The institution was designed to train experts with master's and doctoral degrees in high-tech fields.

In 1989, KIST was separated from KAIST and tasked with founding new institutes targeting the country's emerging technological priorities. When these institutes failed to address the urgent needs of industry, the government responded by founding the Korea Academy of Industrial Technology (KAITECH), which has since utilized approximately $200 million in public funding annually. A significant step came in 1979 when the government established the Korea Institute of Electronic Technology (KIET) to lay the technological foundation for the semiconductor industry and the Korea Telecommunications Research Institute (KETRI) to support telecom-related sectors. After meeting its objectives in the 1980s, KIET and KETRI were merged to form the Electronics and Telecommunications Research Institute (ETRI), tasked with conducting research in areas such as Integrated Services Digital Network (ISDN), optical communications, optoelectronics, and satellite systems (Göker, 2000: 12).

Overall, South Korea's post-1980 technology policy underwent a significant transformation. The government accelerated efforts to establish a national innovation system, with a substantial portion of R&D being undertaken by private firms or public-private partnerships. Public research institutions shifted their focus toward advanced technologies and increasingly functioned as intermediaries between university laboratories and industry. The policy toward technology acquisition also evolved—restrictions on foreign technology transfer were gradually lifted, enabling a more liberalized approach. Centralized planning and implementation characterized R&D governance, which allowed for the formulation of long-term strategies for specific technologies and products.

The evolution of South Korea's major export sectors by decade is illustrative of its technological advancement (Ayhan, 2002: 327–328):

- **1960s**: Mining and agricultural products

- **1970s**: Textiles, plywood, consumer electronics, steel, shipbuilding, and basic service industries
- **1980s**: Televisions, video cassette recorders, automobiles, microwave ovens, and basic machinery
- **1990s**: Semiconductors, flat panel displays, multimedia products, telecommunications equipment, HDTVs, advanced machinery, and precision instruments

In acquiring and producing technology, South Korea did not rely heavily on foreign capital investments. Instead, the country opted for importing capital goods and developing domestic capabilities. The education system established during the 1960s to support the imitation of foreign technologies yielded strong outcomes. When supported by effective R&D efforts, this system enabled South Korea to develop its own technological capabilities (Alçın, 2010: 135–136).

4.2. Technoeconomic Policies in Turkiye

Science and technology are among the most critical components in determining a country's level of development. For a nation to progress, it must first establish a solid foundation in these areas. Building such an infrastructure requires setting clear priorities and formulating long-term plans that can contribute to sustainable advancement. This section of the study will provide a periodical examination of the science and technology policies implemented in Turkiye.

4.2.1. Technoeconomic Policies in the Pre-1980 Period

To understand the perspective on science and technology within Turkiye's development plans, it is essential to analyze the efforts and attitudes towards these fields prior to 1980. This section of the study focuses on the techno-economic policies pursued during the pre-1980 period.

During the pre-Republic era, the progress made by Europe in science and technology from the 17th century onwards created a noticeable gap between Western nations and the Ottoman Empire. Recognizing this disparity in the 18th century, the Ottoman state began efforts to catch up. While the Renaissance and Enlightenment periods fostered scientific advancement and intellectual transformation in Europe, the Ottoman Empire struggled to establish sustained development in science despite initial initiatives. Following the collapse of the Empire, the newly established Republic of Turkiye, guided by a nation-state model, prioritized economic reform and began laying the groundwork for such transformation (Yıldız, Ilgaz & Seferoğlu, 2010: 458).

Between 1930 and 1945, in response to the global economic depression of 1929, Turkiye adopted a state-driven industrialization model, initiating one of the world's earliest national planning efforts. With the launch of the First Five-Year Industrial Plan in 1934, a new era of planned industrial development began, aiming to reduce dependency by producing essential goods domestically. Many key industrial facilities were established under this plan (Soyak, 2006). The success of this initiative led to the drafting of a Second Five-Year Plan; however, its implementation was halted by the outbreak of World War II.

Although Turkiye remained neutral during the war (1946–1953), its economy suffered considerable setbacks. Investments in industry were suspended in favor of defense spending. Toward the war's end, planning activities resumed with the introduction of the 1946 "Urgent Industrial Plan." Yet, with Turkiye joining the IMF in 1947, a shift occurred, and focus moved toward the formulation of the 1947 Turkish Economic Development Plan. During this period, characterized by free-market policies and a liberal import regime, industrial development stagnated.

Between 1954 and 1961, state intervention in the economy resumed. Import restrictions were reintroduced, and the focus on industrialization intensified.

From 1962 to 1979, Turkiye entered a phase in which economic development was guided by planned strategies. Until 1960, industrialization had taken precedence over science and technology, with the latter being treated mostly within the context of technology transfer (Alçın, 2010). The First Five-Year Development Plan (1963–1967) emphasized the importance of using advanced technologies and improving technical expertise. Policies were proposed to strengthen technology transfer, education, and R&D efforts (cited in Alçın, 2010). The establishment of the Scientific and Technological Research Council of Turkiye (TÜBİTAK) during this period marked a significant step in science policy (Yıldız, Ilgaz & Seferoğlu, 2010: 460).

Turkiye also participated in the "Pilot Teams on Knowledge and Economic Development" project led by the OECD in 1962. This project aimed to define Turkiye's long-term objectives for economic development and social welfare and to outline a strategy for science and technology. However, despite these efforts, no coherent techno-economic strategy was formed, and import-substitution policies continued.

The Second Five-Year Development Plan (1968–1974) acknowledged the importance of analyzing and adapting technological developments from early industrialized nations. As in the previous plan, the industrial sector was seen as the main engine of economic growth (Yıldız, Ilgaz & Seferoğlu, 2010: 460).

During the Third Five-Year Development Plan (1975–1979), the necessity of modern technology for development was underlined. The emphasis was on acquiring technologies that matched the country's needs and improved living standards. Infrastructure development for technology imports was also highlighted. Nonetheless, tariff reductions, export difficulties, a limited domestic market, and the ongoing use of import-substitution strategies contributed to economic stagnation (Soyak, 2011: 86).

The Fourth Five-Year Development Plan (1979–1983) advocated a state-led industrialization model and outlined a broader framework for science and technology policy (Alçın, 2010: 187). Despite continued adherence to import-substitution, the industrial structure during this time showed signs of systemic weakness. Low capital intensity, an unskilled labor force, outdated labor-intensive technology, and inefficient production all contributed to a deepening economic crisis (Soyak, 2011: 87).

4.2.2. TechnoEconomic Policies in the Post-1980 Period

Following the 1980s, Turkiye's economic structure underwent a significant transformation with the implementation of the January 24, 1980 decisions, steering the country into a neoliberal framework that continues to this day. This period marked a departure from traditional development economics, shifting towards a model centered on technology-driven growth.

In line with this transformation, Turkiye introduced its first official "Turkish Science and Technology Policy" document, covering the years 1983 to 2003. The science and technology objectives outlined in this policy, as well as in the Fifth Five-Year Development Plan, serve as the main reference points for analyzing the period between 1980 and 1990.

At the beginning of the 1980s, a collaborative effort between the State Planning Organization (DPT) and the Scientific and Technological Research Council of Turkiye (TÜBİTAK) resulted in the drafting of the "Turkish Science and Technology Policy: 1983–2003" document, which represented the country's first comprehensive attempt at formulating a detailed science and technology strategy. During a time when technological change was accelerating globally, trends such as technological renewal in products, processes, and management practices, flexible manufacturing and automation, total quality management, the globalization of markets and services, and the commercialization of knowledge increasingly defined the new economy. Turkiye's policy framework between 1983 and 2003 was shaped with reference to these global dynamics (Ayhan, 2002: 341).

To strengthen the national research and science system, several measures were proposed, including the establishment of the Supreme Council for Science and Technology (BTYK) under the leadership of the Prime Minister. This council was tasked with assessing Turkiye's research and development (R&D) capabilities, workforce, and expenditures in accordance with international standards. Long-term goals for Turkiye's advancement in science and technology were also set. Among these targets were objectives such as achieving an annual 15% increase in R&D spending, allocating research funds according to priority areas, and raising the share of R&D expenditures in GDP to 2% by 2003. In addition, strategies to enhance both the quantity and quality of researchers were outlined.

Broadly speaking, Turkiye aimed to improve its standing in the global scientific community: from 41st place in 1981 to entering the top 30 by 1993 and reaching the top 20 by 2003. Although the Turkish Science and Technology Policy of 1983–2003 was the first official document outlining clear aims and objectives for scientific and technological development, it largely remained unimplemented and instead laid the groundwork for the 1993–2003 policy framework (Özdaş, 2000: 41 et seq.).

Similarly, the Fifth Five-Year Development Plan (1985–1989) adopted the Turkish Science and Technology Policy as a guiding framework. It focused on promoting research and development activities aimed at addressing the country's economic, social, and industrial challenges. Furthermore, it emphasized the adaptation of new and advanced technologies to local conditions and encouraged private sector engagement in technology adoption and innovation (Ministry of Development, Fifth Five-Year Development Plan).

After 1990, Turkiye's science and technology policies will be analyzed within the framework of the national development plans and the National Science, Technology, and Innovation Strategies, which are considered important for evaluating the direction and effectiveness of the country's efforts since 1990. This evaluation covers the period starting with the Sixth Five-Year Development Plan and extends through to the Tenth Five-Year Development Plan, currently in effect, assessing the extent to which the science and technology objectives set out during these phases have been achieved.

The Sixth Five-Year Development Plan (1990–1994) marked a departure from the previous five plans by setting the ambitious goal of transforming Turkish society into an "information society." For the first time, the plan formally introduced specific "Science and Technology Goals," including targets such as doubling the number of personnel engaged in R&D activities and increasing R&D expenditures to 1% of the Gross National Product (GNP).

During this planning period, significant legislative and institutional developments took place. The "Turkish Patent Institute Law" was enacted, leading to the establishment of the Turkish Patent Institute, which became operational in 1994. Additionally, with the founding of the Technology Development Foundation of Turkiye (TTGV), new mechanisms for providing R&D support to industrial sector projects were introduced, further promoting innovation and technological advancement in the private sector.

An important milestone in Turkiye's science and technology journey was the document titled *Turkish Science and Technology Policy: 1993–2003*, which was submitted by TÜBİTAK to the Supreme Council for Science and Technology (BTYK) in 1993. After providing a general introduction, the document presents a detailed overview of the country's status in the field of R&D as of 1990 (TÜBİTAK, Turkish Science and Technology Policy 1993–2003).

According to the data provided:

- Number of Researchers:
    - Universities: 28,555
    - Public Institutions: 6,119
    - Private Sector Organizations: 3,203
    - **Total**: 37,877

The full-time equivalent (FTE) number of researchers stood at 16,246, with a ratio of 7 researchers per 10,000 people. R&D expenditures as a percentage of GDP were reported at 0.33%. The distribution of R&D expenditures by institutions was as follows:

- Universities: 69%
- Public Institutions: 13%
- Private Sector: 18%

In terms of scientific publications, Turkiye ranked 40th globally at the time. Based on this assessment, several key challenges were highlighted:

- Resources allocated to R&D activities were insufficient.
- The number of researchers was inadequate, and issues regarding research quality were noted.
- Research and development activities at universities were weak due to heavy teaching loads.
- Access to scientific books and publications for R&D purposes was limited.

After presenting the existing conditions, the document outlined several targets for the 1993–2003 period (Özdaş, 2004: 52–53):

- Increasing the number of researchers to 15 per 10,000 people,
- Raising the share of R&D expenditures in GDP to exceed 1%,
- Moving Turkiye up to 30th place globally in terms of scientific contributions,
- Increasing the private sector’s share of total R&D expenditures to 30%.

This report set out the necessary measures and targets aimed at advancing the country's capabilities in science and technology. Although the intended goals were not fully achieved within the projected timeline, the policy framework laid the groundwork for subsequent initiatives and strategic plans.

As a result of these efforts, laws were enacted to establish institutions such as the Turkish Patent Institute, the National Metrology Institute, the Turkish Academy of Sciences (TÜBA), the Technology Development Foundation of Turkiye (TTGV), and the Turkish Accreditation Agency. In 1998, a project aimed at connecting universities through a national information network was realized, leading to the official establishment of the National Academic Network and Information Center (ULAKBİM).

The Eighth Five-Year Development Plan (2001–2005) aimed to transform Turkiye into an internationally competitive "information society" by fostering scientific and technological progress. The plan emphasized the development of physical, human, and legal infrastructures, set a target to increase R&D expenditures to 1.5% of GDP, and aimed to raise the number of full-time equivalent researchers to 20 per 10,000 economically active individuals.

In alignment with these objectives, the *National Science and Technology Policies 2003–2023 Strategy Document* was introduced. Designed to help Turkiye reach the "contemporary civilization level" envisioned by Atatürk by the centennial of the Republic, the strategy focused on creating a prosperous society that is proficient in science and technology, capable of consciously utilizing and developing new technologies, and able to translate technological advancements into societal and economic benefits.

The main objectives of this project included:

- Identifying long-term trends in global science and technology,
- Assessing Turkiye's current status in science and technology,
- Defining Turkiye's science and technology needs for 2023,
- Determining strategic technologies essential for achieving these goals,

- Proposing policies for the development and/or acquisition of these technologies.

The *Vision 2023* initiative consisted of four sub-projects:

- Technology Foresight Project,
- National Technology Inventory Project,
- Researcher Information System (ARBİS),
- TÜBİTAK National Research Infrastructure Information System (TARABİS).

Within the *2003–2023 Strategy Document*, a roadmap was outlined, emphasizing science and technology as two critical strategic pillars. To secure a competitive global position, Turkiye set the following objectives:

- Mastering flexible manufacturing and automation processes and technologies,
- Developing knowledge-intensive and high value-added products and becoming a global hub for the design and production of consumer goods,
- Acquiring capabilities for clean production technologies,
- Enhancing competitiveness in agriculture-based production,
- Advancing in space and defense technologies,
- Strengthening capabilities in material sciences and technologies.

To improve the quality of life, the following goals were targeted:

- Ensuring food safety and security,
- Achieving excellence in health and life sciences,
- Establishing capabilities for modern, healthy urbanization and infrastructure,
- Developing modern and safe transportation systems.

For sustainable development, the objectives included:

- Gaining proficiency in energy technologies,
- Advancing in environmental technologies,
- Acquiring the ability to utilize natural resources efficiently.

In the field of Information and Communication Technologies (ICT), the *National Science, Technology and Innovation Strategy (UBTYS) 2011–2016* was developed to contribute to Turkiye's 2023 national targets. ICT was identified as one of the areas with strong R&D and innovation capacity. The UBTYS served as a comprehensive document outlining the country's vision, priorities, and main goals in science, technology, and innovation.

Within this strategy, significant emphasis was placed on:

- Enhancing human resources in science, technology, and innovation (STI),
- Encouraging the commercialization of research results,
- Promoting a collaborative culture in multi-partner, multi-disciplinary R&D and innovation activities,
- Strengthening the role of SMEs in the innovation ecosystem,
- Increasing the contribution of research infrastructures to the national research and innovation ecosystem (TARAL),
- Promoting international collaboration in STI in alignment with national interests (TÜBİTAK, National Science, Technology and Innovation Strategy 2011–2016).

The *Tenth Five-Year Development Plan* (2014–2018) was formulated as a major milestone towards achieving Turkiye's 2023 goals, aiming to elevate the nation to a high level of prosperity. The plan was prepared in a global environment characterized by ongoing economic risks, uncertainties, transformations, and newly emerging balances between developed and developing countries.

The Tenth Development Plan was designed not only to ensure high, stable, and inclusive economic growth but also to promote the rule of law, foster a knowledge society, enhance international competitiveness, advance human development, and ensure the protection and sustainable use of environmental resources. The plan adopted a holistic and multi-dimensional approach to economic and social development, embracing a participatory model centered around human-focused development (Ministry of Development, Tenth Five-Year Development Plan).

4.3. Turkiye’s Level of Technological Advancement

When analyzing the economic development achievements of advanced countries around the world, it becomes evident that technology has played a crucial role in the strategies they pursued. As technology has become a fundamental factor in enhancing competitiveness, possessing technological capabilities has turned into an indispensable necessity for nations. Similarly, Turkiye aims to reach the technological standards of developed countries in its efforts to boost economic growth and improve societal welfare.

This section will examine Turkiye’s current state of advancement in the context of science-based development.

4.3.1. An Assessment of Turkiye’s Success within the Framework of Science and Technology Policies

The science and industrialization policies initiated under the leadership of Mustafa Kemal Atatürk in the 1930s yielded significant achievements in Turkiye. However, the education and science policies pursued by political parties up until 1963 largely lagged behind contemporary needs, and substantial progress in these areas was not achieved. To enhance the country's scientific and technological activities, the State Planning Organization (DPT) was established, followed by the founding of the Scientific and Technological Research Council of Turkiye (TÜBİTAK) in 1963, aiming to steer scientific endeavors more effectively. Despite the formulation of five-year development plans intended to drive national growth and economic expansion, many of the projected plans and projects could not be realized within the anticipated timeframes. As a result, Turkiye made limited progress in science and technology, leading to a widening gap with the developed world.

In 1989, during the dissolution of the Eastern Bloc and the collapse of the Soviet Union, Western countries successfully attracted thousands of skilled scientists who had become unemployed in these regions. Turkiye, however, failed to capitalize on this opportunity. At the same time, around 45,000 engineers, technicians, and basic scientists who emigrated from Russia and Ukraine to Israel played a pivotal role in elevating Israel’s technological capacity to its current advanced level.

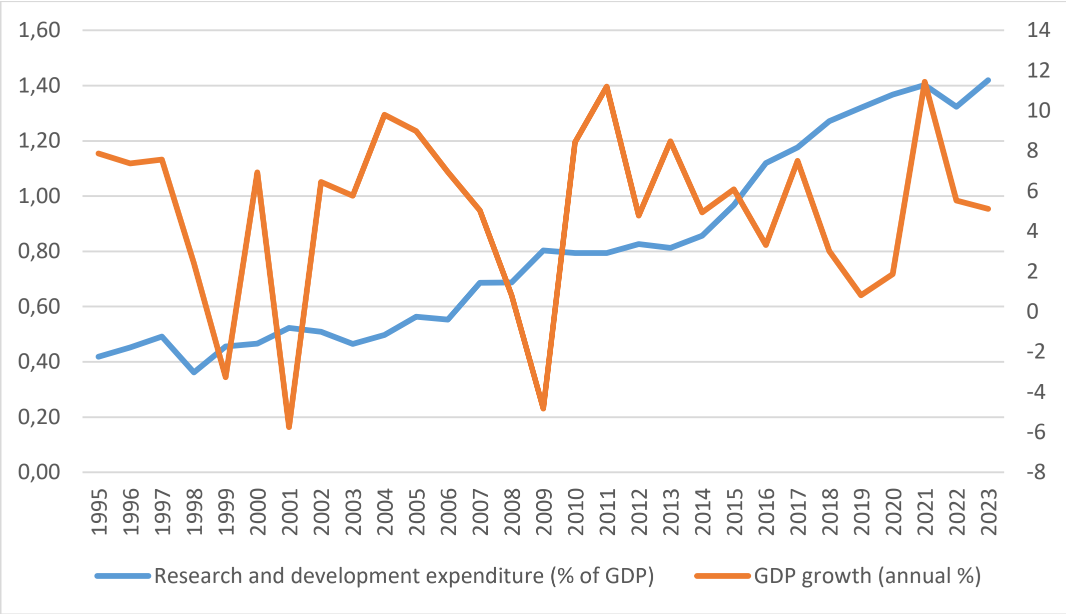
It can be argued that persistent political instability, the inability of successive governments to fully implement consistent science and technology policies, recurring economic crises, and insufficient allocation of resources to this sector have all contributed to Turkiye's failure to meet its intended targets.

4.3.2. An Evaluation of Turkiye in Terms of Research and Development (R&D)

During the 1990s, awareness of the positive impacts of research and development (R&D) began to rise significantly in Turkiye. By 1995, the idea of providing project-based government support to institutions engaged in R&D activities had come into focus. The Turkish Technology Development Foundation (TTGV) was appointed to oversee and carry out activities in this domain.

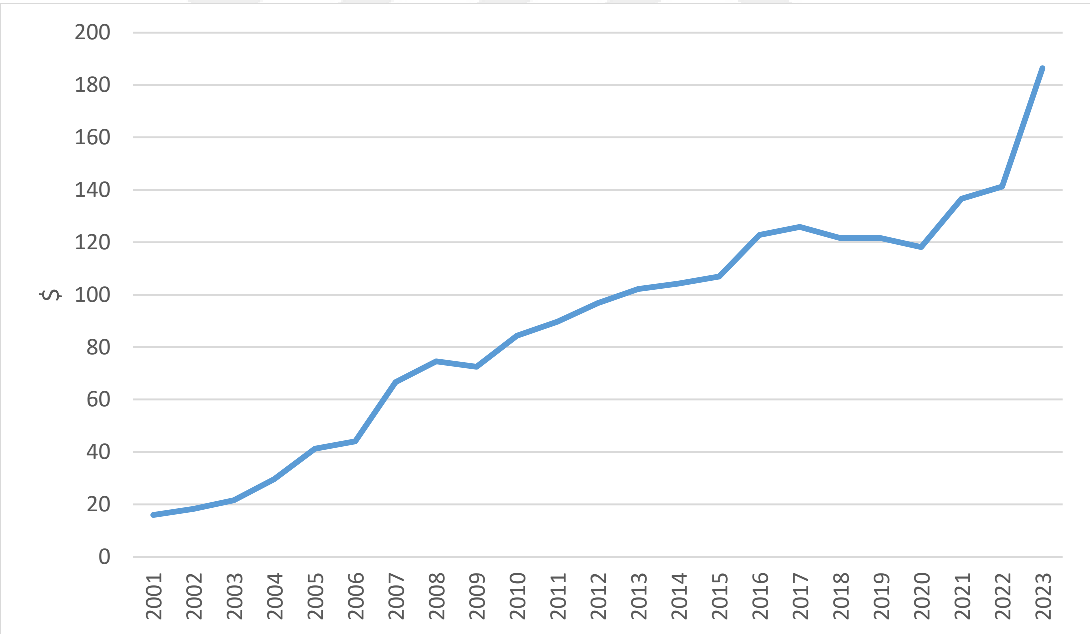
One of the primary reasons for Turkiye's lag in science and technology compared to other nations lies in its strategic preference for importing technology rather than producing it. Instead of adopting a technology policy that focused on import substitution and developing indigenous innovations, Turkiye chose to rely on acquiring technology through foreign currency earned from exports. As a result, the country has not been able to cultivate a self-sufficient technological production capacity and has remained dependent in this field. In contrast, South Korea, which embarked on development planning around the same time as Turkiye, implemented a successful import-substitution technology strategy. Today, it ranks among the leading countries in science and technology. (Ayhan, 2002: 347–349)

A common feature among countries that have achieved industrial success is their commitment to central R&D planning and their consistent prioritization of innovation. Although Turkiye lagged in this regard for many years, in more recent times, the country has started to increase its focus on R&D, providing incentives and expanding its efforts in this strategic area.



Source: World Bank database & Turkstat

Figure 2. The Ratio of R&D Expenditures to Gross Domestic Product (GDP) and GDP Growth (annual %)



Source: World Bank database & Turkstat

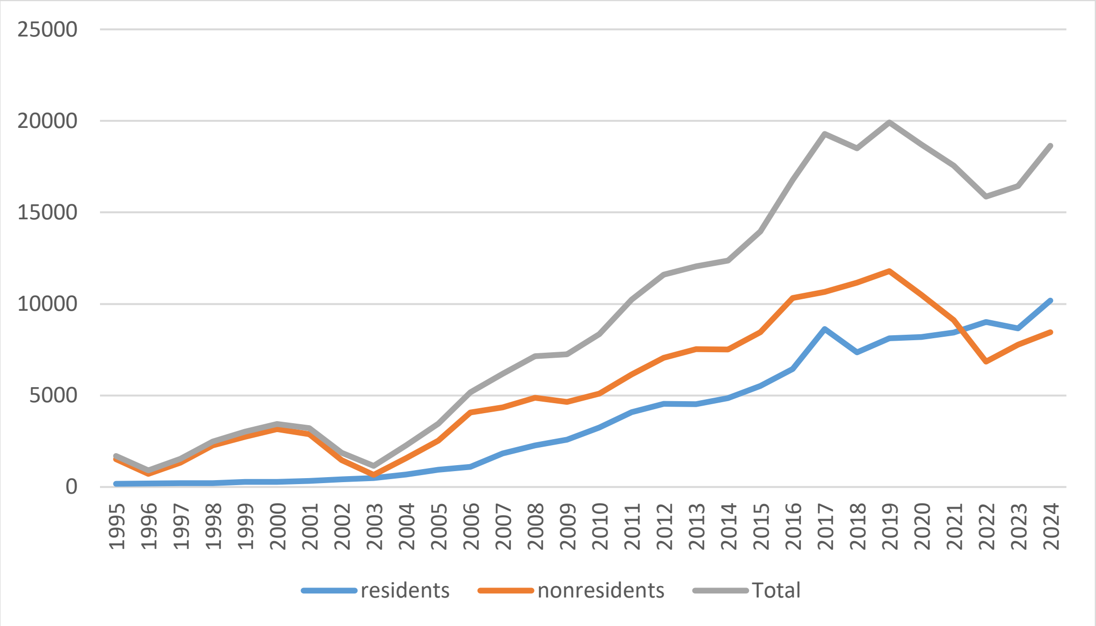
Figure 3. R&D Expenditure Per Capita

Within the scope of comparisons made with OECD countries, the data presented in this study utilizes the Purchasing Power Parity (PPP) indicators (USD: 1.00) published by TURKSTAT.

As can be observed from the figures, although Turkiye has increased its focus on R&D in recent years by allocating more resources, training qualified human capital, and enhancing its activities in this field, the desired level of outcomes has yet to be fully achieved.

4.3.3. An Evaluation of Turkiye in Terms of Patents

When assessing Turkiye's global standing in the field of patents, it becomes clear that countries such as the United States, Japan, Germany, and South Korea — which have made significant advances in patent activity — remain well ahead of Turkiye.



Source: Turkish Patent and Trademark Office, 2025

Figure 4. The Annual Distribution of Applications Submitted to the Turkish Patent Institute

In Turkiye, the majority of patents granted by the Turkish Patent Institute (TPE) are held by foreign entities. Among the countries receiving the most patents based on scientific work in Turkiye, the United States leads, followed by Germany (Karaöz ve Albeni, 2004: 4).

Patent statistics are widely regarded as a key indicator of a country's level of development. Nationally obtained patents serve as evidence of a country's progress in science and technology. When comparing Turkiye with economically advanced countries, it becomes clear that Turkiye still lags in this area. However, recent technological initiatives suggest that the country has the potential to make significant progress in patent generation.

4.3.4. Evaluation of Turkiye in Terms of a National Innovation System and Recommendations

Nations that acknowledge the critical role of science and technology in development—whether developed or developing—have adopted various strategies to enhance their technological capabilities. Since the early 1950s, Turkiye pursued an industrialization strategy heavily reliant on assembly-based manufacturing to acquire technology. However, due to stagnation in political, economic, and social spheres, Turkiye failed for many years to establish an industrial base capable of generating indigenous technologies.

With the economic liberalization policies introduced on January 24, 1980, Turkiye began to open up to global markets, and industrial development gained prominence in the national agenda. By the 1990s, knowledge-based industrialization had become widespread worldwide. However, Turkiye was unable to keep pace with this global trend. One of the main reasons for Turkiye's delayed entry into the global science and technology race lies in its failure to build a functional national innovation system. Moreover, past efforts have not been widely adopted, nor has there been sufficient determination or consistency in implementing necessary reforms (Ayhan, 2002: 296).

To respond to the question of what an effective national innovation system should look like for Turkiye to achieve success, the following points can be proposed (Ayhan, 2002: 293–295):

- **In the field of education**: Emphasis should be placed on practical learning rather than purely theoretical instruction. Graduate education must be prioritized. The number and quality of vocational schools should be increased. Academic research must be commercialized and patented. Compulsory education should be extended to at least 11 years, and students at all levels of the education system should be made aware of entrepreneurship.
- **In the social sphere**: A cultural environment should be created that encourages individuals to take risks and focus on success. Brain drain must be reversed,

and the departure of highly qualified scientists to foreign countries should be minimized.

- **In techno-economic policy**: Strategic sectors in science and technology for the future must be identified, and targeted policies must be developed to support them.
- **In the field of R&D**: Legal frameworks that foster and encourage innovation must be implemented. Additionally, long-term and high-cost research in advanced technologies should receive sufficient financial support.
- **In the field of patents**: Universities and private sector professionals should be encouraged to produce more patents, which are widely recognized as indicators of innovation in technology-producing countries.
- **Within the innovation system**: "Innovation Monitoring and Transfer Centers" should be established to ensure the operability of national innovation systems. Furthermore, a robust innovation model must be developed that ensures strong interaction between the government, universities, and the private sector.

5. EMPIRICAL ANALYSIS

This section covers the methodology, data set and econometric findings used to empirically examine the relationship between technological development and economic growth in Türkiye.

5.1. Methodology

The econometric methodology used to empirically examine the short- and long-run relationships between technological development and economic growth in Türkiye is described. The primary objective of the analysis is to test theoretical expectations proposed in the literature using time-series data and to statistically understand the impact of technology-focused policies on growth. In this context, the empirical design, hypotheses, the dataset used, and the measurement variables are presented. Then, the Distributed Autoregressive Lag (ARDL) approach, which allows for examining the cointegration relationship between variables in both the short and long run, is presented.

5.1.1. Research design and Hypotheses

This study is a quantitative time series study that aims to examine the causality and impact mechanisms between technological development and economic growth in the Turkish economy. The basic design of the analysis focuses on understanding how short-term shocks affect the long-term equilibrium relationship. The research design for this purpose is illustrated in Figure 5.

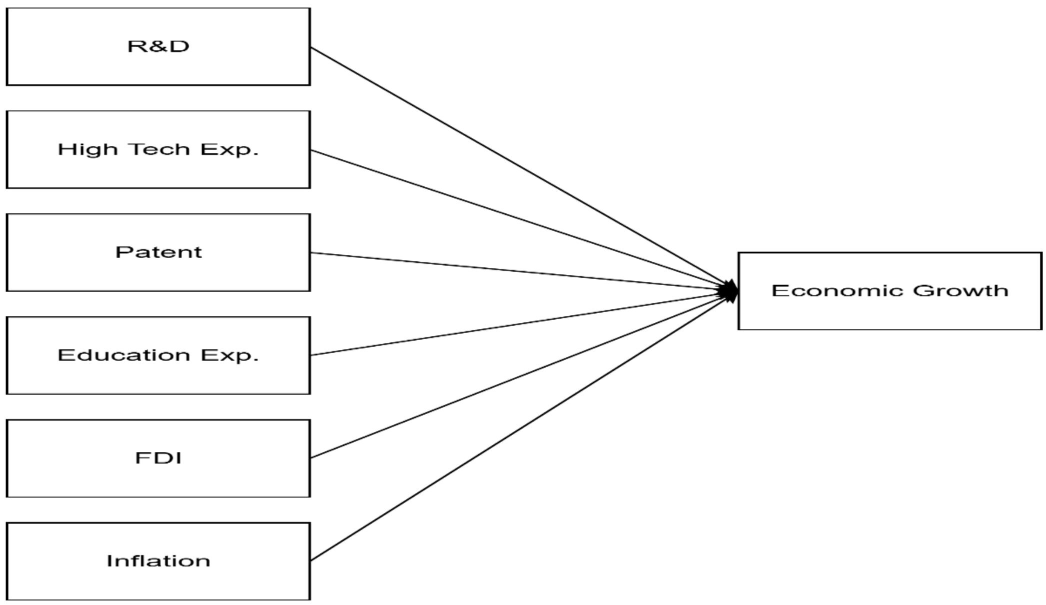


Figure 5. Research Design

Based on technology-growth theories in the literature, the following are the main hypotheses developed for this empirical analysis:

Table 1. Variables Used in the Study Research Hypotesis

Hypothesis No.	Name of the Hypothesis	Explanation and Expectation
H1 (Co-integration)	Long-Term Relationship Hypothesis	It is assumed that there is a long-term cointegration relationship between the variables included in the analysis.
H2 (R&D)	Innovation Input Effect	R&D expenditures within GDP are expected to have a positive and significant impact on economic growth in the long run.
H3 (Export)	Technological Output Effect	The increase in the share of medium and high-technology exports is expected to have a positive and significant impact on economic growth by increasing the country's competitiveness and growth performance.
H4 (Patent)	Innovation Impact	The increase in the number of established patents is expected to have a positive and significant impact on economic growth by reflecting the country's innovation capacity and knowledge accumulation.

Testing these hypotheses will offer important policy implications regarding the role of technology and innovation in Turkiye's growth strategies.

5.1.2. Data

The study utilizes annual time series data for the Turkish economy spanning the period 1995-2023. The study period was determined in this way due to the lack of consistent and reliable access to the full set of variables used in the analysis before 1995, particularly due to limitations in high-technology exports and internationally accepted R&D expenditure data. This time period offers the advantage of reflecting the significant structural changes and technological policies of the Turkish economy (especially the increased focus on technology and innovation since the 2000s). The data used in the analysis were compiled from internationally accepted and proven reliable sources.

The number of registered patents variable, as a direct indicator of national innovation output, was obtained from the official database of the Turkish Patent and Trademark Office (TÜRKPATENT), while all other variables—GDP, R&D expenditures, high-tech exports, education expenditures, foreign direct investment, and inflation data—were obtained from the World Bank Development Indicators (World Development Indicators - WDI).

The variables used in this study were selected to test the theoretical relationships between technological development, fundamental macroeconomic factors, and economic growth. The variables used in the study and their abbreviations are presented in Table 3.

Table 2. Variables Used in the Study

Variable Name	**Abbreviation**	**Variable Type**	**Source**	**Unit of Measurement / Conversion**
Gross Domestic Product	ln(GDP)	Dependent	World Bank	Current USD (Log)
R&D Expenditures	RD	Independent	World Bank	Percentage of GDP (%)
Medium and High-Tech Exports	HTX	Independent	World Bank	Percentage of Manufacturing Exports (%)
Number of Residental Patents	ln(PATENT)	Independent	TÜRKPATENT	Number (Logarithmic)
Education Expenditures	EDU	Control	World Bank	Percentage of GNP (%)
Foreign Direct Investment	FDI	Control	World Bank	Percentage of GDP (%)
Inflation (CPI)	INF	Control	World Bank	Annual Percentage Change (%)

The dependent variable of the study, Economic Growth, was measured as the natural logarithm of the Gross Domestic Product (GDP) data in current US dollars (ln(GDP)). GDP is the most comprehensive indicator of a country's economic activity and is accepted as the fundamental and standard measure of growth in macroeconomic studies. Logarithmic transformation is a preferred method in time series analysis to balance the variance of variables and minimize the effects of large values, thereby obtaining more reliable results (Stock & Watson, 2015).

Technological development has been incorporated into the model with variables representing three different dimensions. The first variable used is Research and Development Expenditure (RD). Measured as a percentage of GDP, RD expenditure represents the input dimension of the technology and innovation process. Endogenous Growth Theories (Romer, 1990; Aghion & Howitt, 1992) argue that R&D investments increase the stock of new knowledge, leading to non-exogenous and continuous growth. Therefore, it is hypothesized that R&D expenditure has a positive and significant long-term effect on economic growth.

Another variable is medium and high-tech exports (HTX). Expressed as a percentage of total manufacturing exports, this variable is an output indicator that reflects the country's technological capacity and competitive strength. The increase in high-tech product exports indicates that local firms are able to commercialize their technological knowledge internationally. This creates positive externalities on growth, accelerating development (Grossman & Helpman, 1991).

The third independent variable is the number of registered patents (ln(PATENT)). The natural logarithm of registered patent applications filed with the Turkish Patent and Trademark Office is a concrete indicator that certifies the country's actual innovation output. Patents facilitate the incorporation of new technologies into the economy by encouraging investment and risk-taking through the protection of intellectual property. The logarithmic transformation was used to balance the high volatility and generally non-zero changes in the patent data.

To enhance the robustness of the model and isolate the causality between technological progress and growth, three critical macroeconomic variables were controlled. In this regard, the education expenditure (EDU) variable was used. Measured as a percentage of Gross National Income, education expenditure represents Human Capital. According to Human Capital Theory (Becker, 1964), education expenditure supports economic growth by increasing the productivity and skill level of the labor force and, most importantly, its ability to absorb new technologies.

Another variable is foreign direct investment (FDI). It is measured as net inflows as a percentage of GDP. FDI refers not only to capital inflows but also to the transfer of know-how, management skills, and advanced technology. Through these spillover effects, foreign investment is expected to increase the host country's growth potential (Borensztein, De Gregorio & Lee, 1998).

Finally, the inflation variable (Inflation, consumer prices - INF) was also added to the model as a control variable. Inflation, measured by the annual percentage change in the Consumer Price Index, is an indicator of macroeconomic stability. High and unpredictable inflation rates create uncertainty in the markets, increasing investors' perception of long-term risk and thus negatively affecting capital accumulation and growth. Therefore, inflation is expected to have a negative effect on economic growth (Fischer, 1993).

5.1.3. Variables and their measurement

The study examines the behavior and trends of time series variables, which form the basis of empirical analysis, during the period 1995-2023. Since the dependent variable, Gross Domestic Product (GDP), is used in nominal (current US dollar) values, this variable is expected to exhibit an exponential growth trend over time. This exponential growth is addressed in the econometric model using its natural logarithm (ln(GDP)) to standardize the analysis and balance the variance.

Examining the raw trends of the data and their relationship with the dependent variable in advance is critical to understanding the expected results of the econometric model and potential structural break points. Below, the internal change exhibited by each independent and control variable throughout the period and their simultaneous movements with GDP are examined.

The simultaneous change between Gross Domestic Product (GDP - Current US Dollar) and Research and Development Expenditures (RD - Percentage of GDP), one of our key independent variables, during the 1995-2023 period is shown in Figure 6. Turkiye's GDP series, shown by the blue line, has generally exhibited a strong and exponential growth trend throughout the period under review. Starting at approximately $170 billion in 1995, GDP exceeded the $1 trillion threshold by the end of the period (2023). This upward trend indicates the presence of a stationarity problem in the time series analysis, thus necessitating the use of a logarithmic transformation (ln(GDP)) in the econometric model. The most significant declines and recoveries in the GDP series are observed around the 2001 economic crisis and the 2008-2009 global financial crisis. However, the overall long-term trend is upward.

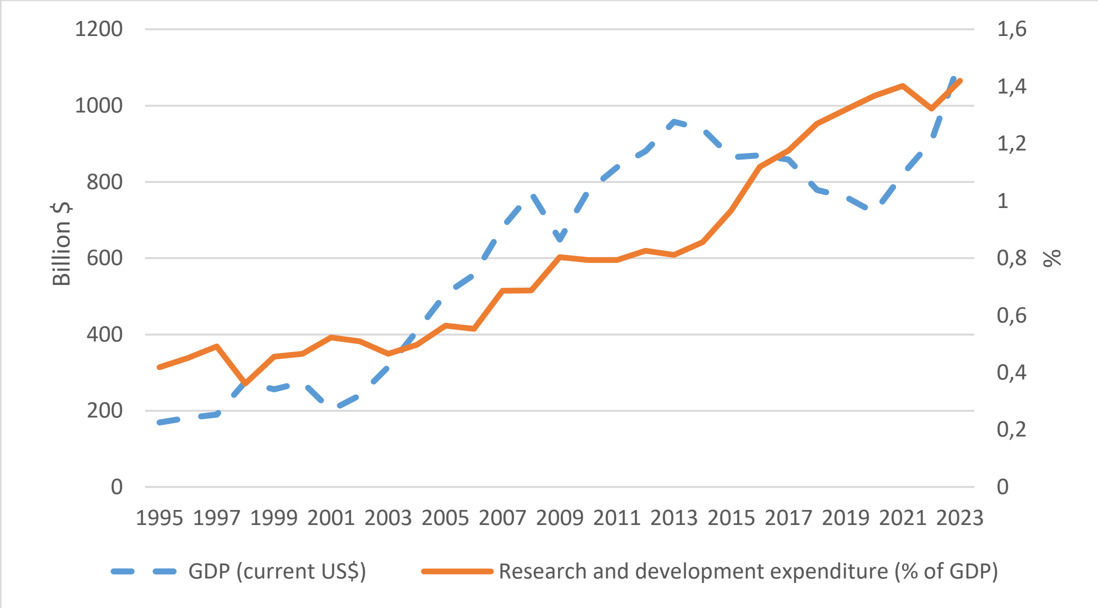


Figure 6. GDP and RD Expenditure

The ratio of R&D expenditures to GDP (RD), represented by the orange line, has shown a systematic and gradual upward trend over the period. This ratio, which was around 0.4% in 1995, gained momentum in the early 2000s and approached 1.4% in the 2021-2023 period, indicating that Turkiye's allocation of resources to innovation inputs has increased significantly over time.

The graph provides the first clues about the existence of a strong positive correlation between GDP and R&D expenditures. Particularly since 2003, a parallel rise in R&D expenditures has been observed alongside rapid GDP growth. This simultaneous movement is consistent with the Endogenous Growth Theory (Romer, 1990). It also supports the notion that investments in technological development are a driving force for economic growth. Although the nominal value of GDP fluctuates during crisis periods, the percentage of R&D expenditures (relative to GDP) shows a more stable and continuous increase, demonstrating that Turkiye's technology-driven growth journey continues despite macroeconomic shocks.

Figure 7 shows the simultaneous trend between GDP (Current US Dollar) and the share of Medium and High-Tech Exports (HTX) in total manufacturing exports, representing technological output, during the 1995-2023 period. The HTX ratio, represented by the orange line, exhibited an interesting two-stage behavior throughout the period. At the beginning of the series (1995-2007), the share of technology exports rose rapidly from approximately 24% to a peak of approximately 44% in 2007. This rapid increase reflects the structural transformation of Turkiye's manufacturing industry in the early 2000s and its integration into global supply chains. However, after 2007, the HTX ratio has largely remained flat or shown a slight downward trend (in the range of approximately 40%-44%). This indicates that even though the volume of exports has increased, the share of high-value-added, medium- and high-tech products in total manufacturing exports has struggled to exceed a certain threshold. This flat trend is a preliminary finding that Turkiye's export structure faces a risk similar to the "middle-income trap," namely a "middle-technology trap".

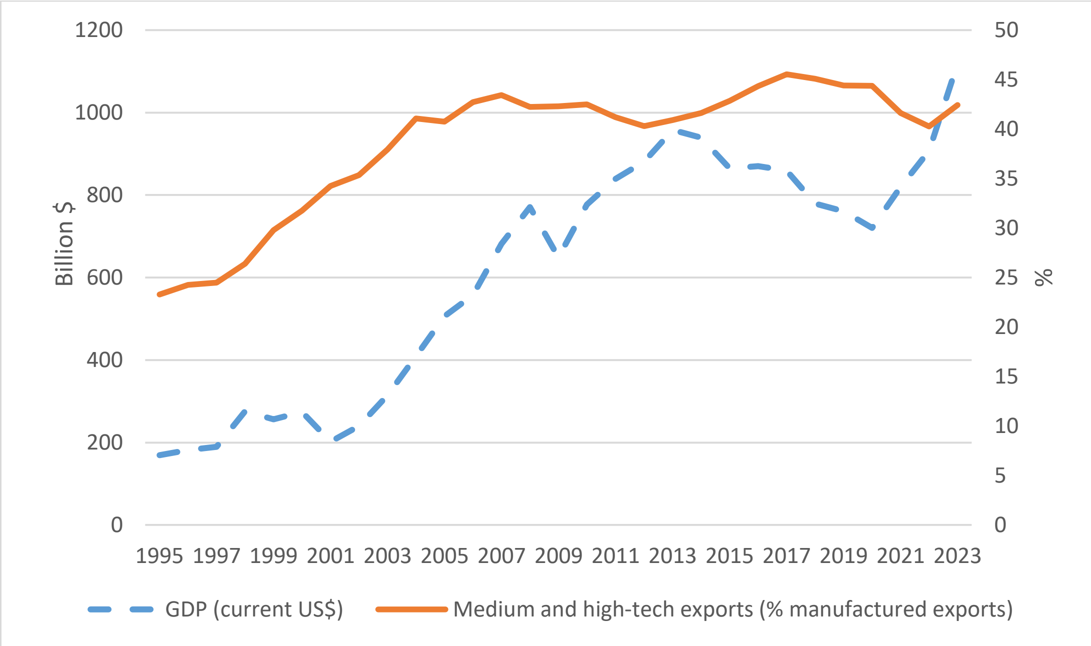


Figure 7. GDP and High-tech Exports

While there was a positive relationship between GDP (blue line) and the HTX ratio in the first phase (1995-2007), it indicates that the relationship was broken or weakened in the second phase (after 2008). On the other hand, the rapid rise in the HTX ratio coincides with a strong increase in GDP, suggesting that technological output supports growth. Moreover, although GDP continued to recover and grow strongly in the post-global financial crisis period, the HTX ratio did not increase in parallel with this growth, but rather fluctuated. This divergence provides preliminary evidence that economic growth in the post-2008 period may be largely driven by other factors such as domestic demand, consumption and nominal value increases rather than high-tech exports.

Figure 8 shows the dynamics between GDP and the number of resident patents, which represents technological innovation output, over the period 1995-2023. Although the number of resident patents will be used logarithmically in the analysis, it is shown in raw numbers in the graph. The patent application series, indicated by the orange line, exhibited an exceptionally strong and continuous upward trend throughout the period. Starting in 1995 at very low levels (around hundreds), the annual number of resident patents started to increase rapidly from 2003 onwards, reaching a value of over 8,000 by the end of the period. This increase can be interpreted as a tangible outcome of the R&D incentives implemented in Turkiye's national innovation system since the early 2000s (especially after 2002) and the increased importance attached to intellectual property rights. Due to its high volatility, the logarithmic transformation (ln(PATENT)) of this variable in the econometric analysis is critical for the reliability of the model.

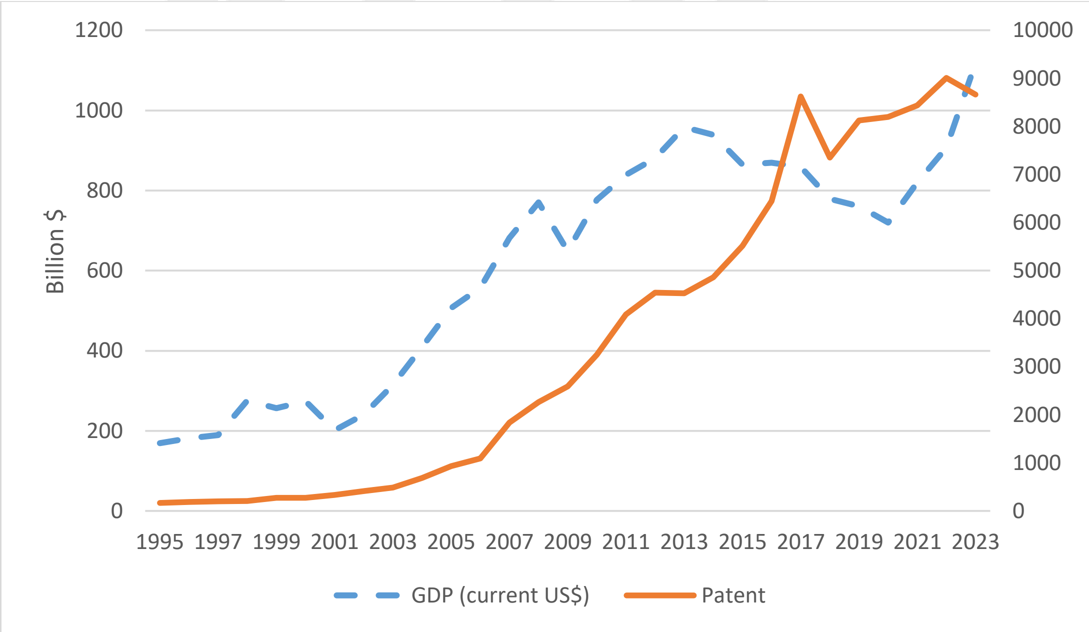


Figure 8. GDP and Patent

It can be said that there is a strong positive relationship between GDP and the number of patents in the long run. Especially between 2003 and 2015, the upward trend in GDP was parallel to the acceleration in patent applications. This suggests that innovative activities (patent output) and economic expansion support each other. On the other hand, despite the decline or flat course of the GDP series in 2008 and 2015-2016, the patent series maintained its upward trend, only showing a slight slowdown in the 2017-2018 period. This suggests that resident innovation efforts are relatively less affected by short-term macroeconomic shocks and exhibit a cumulative structure.

Figure 9 shows the contemporaneous trend between GDP (Current USD) and one of the main control variables, the ratio of Education Expenditure to Gross National Income (GNI) (EDU), over the period 1995-2023. The ratio of education expenditures (EDU), represented by the orange line, has fluctuated but remained generally stable over the period. The series started at around 2.5% in 1995 and fluctuated within a relatively narrow range between 2.2% and 3.0% in the late 1990s and early 2000s. Since the early 2010s (around 2012 onwards), there has been a significant upward trend in the EDU ratio, with expenditures settling in the 3.5%-4.0% of GDP band. This increase shows that Turkiye's resource allocation to the education system has increased quantitatively, supporting the effort to create a qualified workforce in line with the Human Capital Theory (Becker, 1964). In recent years, the ratio has again risen above 4%, reaching one of the highest levels.

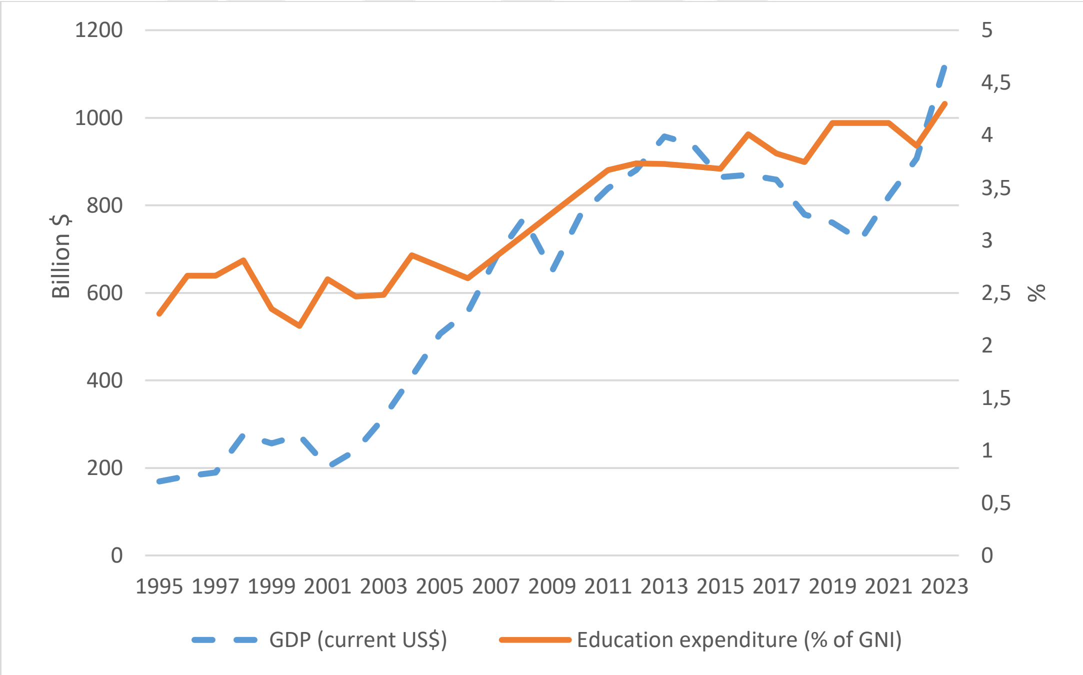


Figure 9. GDP and Education Expenditure

The relationship between GDP and the EDU ratio varies across periods: While GDP increased rapidly in this period, the ratio of education expenditures remained relatively flat and fluctuating. This suggests that in the first phase of economic growth, education investments did not increase at a rate parallel to the increase in GDP. As the nominal value of GDP (hence its logarithmic value) continued to increase, the ratio of education expenditures also stabilized at high levels. The positive co-movement of the two variables in the overall long-run trend is consistent with the expectations that human capital investments (education) and economic growth support each other in the long run.

The change in the ratio of GDP (current USD) and the ratio of foreign direct investment (net inflows) to GDP (FDI), a key control variable, over the period 1995-2023 is presented in Figure 10. The FDI ratio, indicated by the orange line, has been highly volatile over the period. While the series generally fluctuated at low levels (between 0.5% and 1.5% of GDP), it reached a historical peak in 2006-2007. This peak (around 3.7%) can be attributed to large privatization projects and the anticipation of the EU accession negotiations that started in 2005. However, with the 2008 Global Financial Crisis, FDI rates fell sharply and have been highly volatile since then (2009-2023), never approaching the 2006-2007 levels again. In recent years, the ratio has shown a downward trend close to its levels at the beginning of the period.

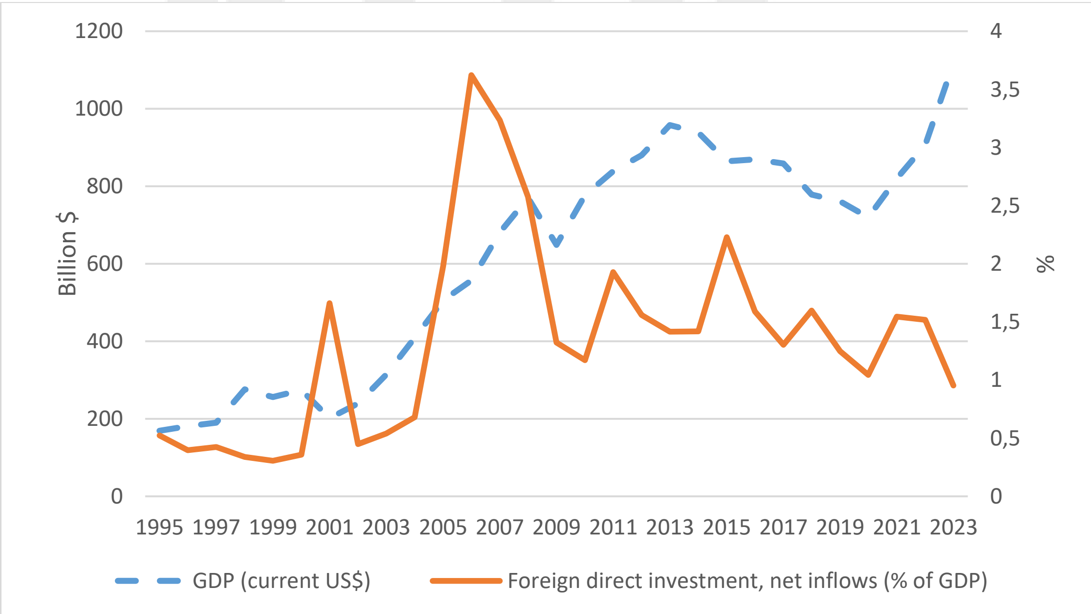


Figure 10. GDP and FDI

The relationship between FDI and GDP is particularly pronounced in key periods. In these years, the extraordinary increase in the FDI rate exhibited a strong positive relationship with the rapid growth in GDP. This supports the theoretical expectation that foreign investment accelerates economic growth through technology transfer and capital flows (Borensztein et al., 1998). On the other hand, after the 2008 crisis, although GDP has recovered and continued to grow in nominal terms, the FDI rate has consistently declined or remained at low levels. This divergence suggests that economic growth in this period was mainly sustained by domestic dynamics (domestic demand, credit expansion, etc.) rather than foreign investment inflows.

Figure 11 shows the change between GDP and inflation (Annual % Change in Consumer Prices) (INF), which represents macroeconomic stability, over the period 1995-2023. The inflation series, indicated by the orange line, exhibits a radical structural change over the period. At the beginning of the series, inflation was at high double and triple-digit levels (between 50% and 90%). This period corresponds to the period when the Turkish economy was struggling with chronic instability and high uncertainty. Thanks to the comprehensive structural reforms and monetary policy discipline implemented in the early 2000s, inflation fell rapidly to single-digit levels from 2004 onwards and remained stable at this low/moderate level (in the 5%-15% band) for a long period (until 2017). On the other hand, in the post-2018 period, inflation rates started a significant upward trend again and reached high double-digit levels in 2022, approaching the levels at the beginning of the period.

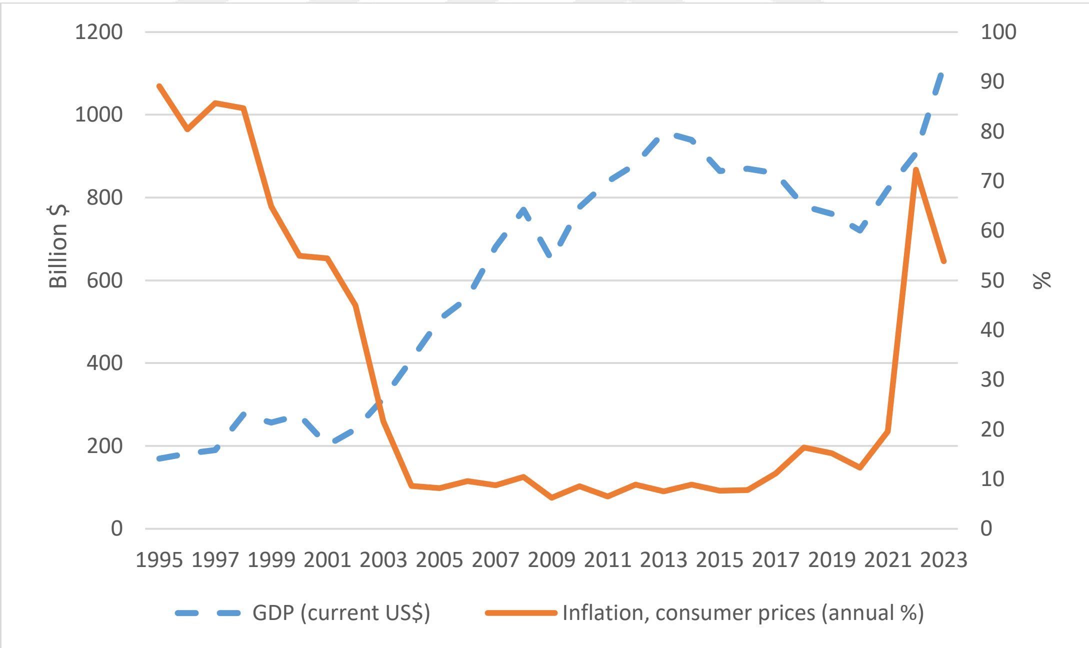


Figure 11. GDP and Inflation

Contrary to expectations, the relationship between GDP and inflation shows an inverse relationship at first glance, but this is due to the use of nominal GDP. The most rapid and sustained nominal increase in GDP (between 2004 and 2015) coincides with the period of the lowest and most stable inflation. This observation is in strong agreement with the theoretical expectation put forward by Fischer (1993) that low inflation supports long-term growth by providing macroeconomic stability. High Inflation and Growth: The peak in the nominal value of GDP at the end of the period coincides with the recent high inflation rates. However, this simultaneous movement may reflect price effects, largely due to the fact that GDP is measured in current (nominal) US dollars. The relationship between real GDP growth and inflation is much more complex and probably negative in this period.

5.1.4. Modelling

In this study, Autoregressive Distributed Lag (ARDL) approach is used to identify the short and long-run dynamic relationships between technological development and economic growth in Turkiye. This approach, developed by Pesaran, Shin and Smith (2001), is particularly preferred for its ability to simultaneously analyze short and long run interactions in time series data.

The choice of the ARDL model is mainly driven by two critical advantages:

i. Unlike traditional co-integration tests (e.g., the Johansen test), the ARDL method does not require the variables included in the model to have the same degree of integration (I(1)). It allows for reliable forecasts even when the variables are I(0), I(1) or a mixture of both.

ii. The ARDL model allows us to estimate both long-run equilibrium relationships and short-run dynamics and the speed of correction of deviations from this equilibrium (Error Correction Mechanism - ECM) in a single step..

The long-run model representing the main relationship of the study can be expressed as follows with ln(GDP) as the dependent variable and all independent and control variables (RD, HTX, ln(PATENT), EDU, FDI ve INF):

$$\mathbf{ln}(\boldsymbol{GDP}) = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(RD) + \boldsymbol{\beta_2}(HTX) + \boldsymbol{\beta_3}\boldsymbol{ln}(PATENT) + \boldsymbol{\beta_4}(EDU) + \boldsymbol{\beta_5}(FDI) + \boldsymbol{\beta_5}(INF) + \boldsymbol{\varepsilon} \tag{1}$$

To test for the presence of co-integration, the ARDL form of the model (Error Correction Model without Lags) is formulated. This form includes both the level and first differences of the variables.

$$\begin{aligned}\Delta\ln(GDP)_t = \alpha_0 &+ \sum_{i=1}^{p} \gamma_i \Delta\ln(GDP)_{t-i} + \sum_{i=0}^{q_1} \delta_{1i} \Delta(RD)_{t-i} + \sum_{i=0}^{q_1} \delta_{2i} \Delta(HTX)_{t-i} \\ &+ \sum_{i=0}^{q_1} \delta_{3i} \Delta(PATENT)_{t-i} + \sum_{i=0}^{q_1} \delta_{4i} \Delta(EDU)_{t-i} + \sum_{i=0}^{q_1} \delta_{5i} \Delta(FDI)_{t-i} \\ &+ \sum_{i=0}^{q_1} \delta_{6i} \Delta(INF)_{t-i} + \lambda_0 \ln(GDP)_{t-1} + \lambda_1 (RD)_{t-1} + \lambda_2 (HTX)_{t-1} \\ &+ \lambda_3 (PATENT)_{t-1} + \lambda_4 (EDU)_{t-1} + \lambda_5 (FDI)_{t-1} + \lambda_5 (INF)_{t-1} + \varepsilon_t\end{aligned}$$

(2)

In this formulation: The terms denoted by the Δ operator represent short-run dynamics. The level terms (λj) are used to test for the existence of a long-run co-integration relationship.

The F-Bounds Test is an unrestricted F-test that investigates the existence of a long-run relationship. The null hypothesis (H_0) and alternative hypothesis (H_1) of the test are as follows:

H_0 : $\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$ (No co-integration relationship.)

H_1 : $\lambda_0 \neq \lambda_1 \neq \ldots \neq \lambda_6 \neq 0$ (There is co-integration relation..)

The calculated F-statistic is compared with the upper and lower critical value limits provided by Pesaran et al. (2001). If the F-statistic exceeds the upper bound (I(1)), H0 is rejected and the existence of a long-run co-integration relationship is confirmed.

Once the existence of a long-run relationship is confirmed, the short-run dynamics and the speed at which the imbalances converge to the long-run equilibrium are analyzed with the Error Correction Model (ECM). The ECM is formulated as follows:

$$\Delta\ln(GDP)_t = \alpha_0 + \sum_{i=1}^{p-1} \gamma_i \Delta\ln(GDP)_{t-i} + \cdots + \sum_{i=0}^{q_{k-1}} \delta_{k,i} \Delta(X)_{k,t-i} + \lambda \mathrm{ECM}_{t-1} + \varepsilon_t$$

(3)

The coefficient λ in this model is the coefficient of the Error Correction Term (ECM_{t-1}). This coefficient is expected to be negative, significant and between -1 and 0. This value reveals the speed of adjustment of the economic system by showing what percentage of the deviations from the short-run equilibrium is corrected to the long-run equilibrium in each period.

5.2. 5.2. Data Analysis

In this section, descriptive statistics of the data used in the study are given and the necessary preliminary tests for model assumptions are made. The analysis and analysis applied in the study were made with Eviews 12 package program.

5.2.1. Descriptive statistics

Before the model estimations, descriptive statistics of the annual time series variables covering the period 1995-2023 are calculated and presented in Table 4. These statistics reflect the central tendency, dispersion and distributional characteristics of each series..

Table 3. Descriptive Statistics of Variables

	LNGDP	RD	HTX	LNPATENT	EDU	FDI	INF
Mean	26,99	0,81	38,53	7,45	3,24	1,34	30,65
Median	27,30	0,79	41,19	7,86	3,26	1,32	12,28
Max.	27,74	1,42	45,54	9,11	4,30	3,62	89,11
Min.	25,86	0,36	23,29	5,14	2,19	0,31	6,25
Std, Dev,	0,61	0,35	6,80	1,45	0,66	0,84	29,60
Skewness	-0,66	0,53	-1,19	-0,36	-0,01	0,91	0,89
Kurtosis	1,86	1,87	3,02	1,55	1,52	3,65	2,15
Jarque-Bera	3,69	2,93	5,79	3,17	2,63	4,50	4,69
Probability	0,16	0,23	0,07	0,20	0,27	0,11	0,10
Observations	29	29	29	29	29	29	29

The number of observations is 29 for all variables. When the Central Tendency indicators are analyzed, it is noteworthy that the means reflect the logarithmic values in the variables with logarithmic transformation (ln(GDP), ln(PATENT)), while the mean values are low in the proportional variables (RD, EDU, FDI). The mean value of the INF (Inflation) variable (30.65) is much higher than the median value (12.28). This indicates that high inflation values at the beginning of the series pull the mean upwards, hence the distribution is skewed to the right.

An analysis of the dispersion indicators reveals that the variable with the highest Standard Deviation (29.60) and Maximum (89.11) is INF. This finding confirms that the inflation series has the highest volatility among macroeconomic variables throughout the period. Among the independent technological variables, HTX (Medium and High Technology Exports) exhibited a higher dispersion than the others with a standard deviation of (6.80).

Dispersion statistics (Skewness and Kurtosis) and Jarque-Bera (JB) test results were used to test the normality assumption of the variables. The Jarque-Bera probability values calculated for all variables are greater than 0.05 at the 5% significance level. This result indicates that the null hypothesis (variables are normally distributed) is not rejected, thus providing statistical evidence that all series are normally distributed. This finding gives a preliminary impression that the basic assumptions for the subsequent stages of econometric analysis are met.

5.2.2. Unit Root Tests

In econometric analysis, determining the stationarity of time series variables is a prerequisite for investigating the existence of a valid co-integration relationship. In this study, the Augmented Dickey-Fuller (ADF) test is applied to determine whether the variables are I(0) or I(1). The null hypothesis (H0) in the ADF test assumes that the series has a unit root (non-stationary).

In order to apply the ARDL bounds test approach, none of the variables should be integrated at second order (I(2)). Table 3 presents the ADF test results for the variables at level and at first difference for three different models (with constant, with constant and trend, or neither - None).

Table 4. Unit Root Test Results

		At Level						
		LNGDP	RD	HTX	LNPATENT	EDU	FDI	INF
Constant	t-Stat.	-1,465	0,577	-3,053	-1,687	-0,744	-2,330	-1,975
	Prob,	***0,536***	***0,986***	***0,0421*****	***0,427***	***0,819***	***0,170***	***0,2955***
Constant & Trend	t-Stat.	-1,467	-2,076	-1,084	0,258	-2,818	-2,215	-0,777
	Prob,	***0,817***	***0,536***	***0,914***	***0,997***	***0,203***	***0,464***	***0,956***
None	t-Stat.	2,407	2,994	1,849	4,645	1,493	-1,054	-1,764
	Prob,	***0,9948***	***0,9988***	***0,9819***	***1,0000***	***0,9631***	***0,2564***	***0,0740****
		At First Difference						
		d(LNGDP)	d(RD)	d(HTX)	d(LNPATENT)	d(EDU)	d(FDI)	d(INF)
Constant	t-Stat.	-4,569	-5,761	-3,030	-4,149	-5,325	-4,760	-4,795
	Prob,	***0,001******	***0,000******	***0,045*****	***0,003******	***0,000******	***0,001******	***0,001******
Constant & Trend	t-Stat.	-4,603	-6,050	-3,622	-4,654	-5,279	-4,740	-5,825
	Prob,	***0,006******	***0,000******	***0,047******	***0,005******	***0,001******	***0,004******	***0,000******
None	t-Statistic	-3,905	-2,106	-2,678	-1,057	-5,761	-4,852	-4,864
	Prob,	***0,000******	***0,036*****	***0,009******	***0,065****	***0,000******	***0,000******	***0,000******

(*** denotes significance at 1%, ** denotes significance at 5%, * denotes significance at 10% level).

The top panel of Table 3 shows the stationarity test results of the variables at level. At the 5% significance level, the null hypothesis (H 0: unit root) cannot be rejected for all other variables except for the HTX variable. The HTX variable was found to be stationary (t-statistic: -3.053, Probability: 0.0421) only in the model with constant term at 5% significance level, indicating that it may be I(0). The other six variables (ln(GDP), RD, ln(PATENT), EDU, FDI and INF) were found to have unit roots at 5% and 10% significance levels, even in different models.

The bottom panel of Table 3 shows the test results after taking the first difference of the variables. For all variables, the t-statistics of the tests taken at first difference are greater in absolute value than the critical values and the probability values are much lower than the 5% significance level (most of them are significant at the 1% level). This implies that all variables become stationary (I(1)) when first differences are taken. For example, the probability value for Δln(GDP) in the model with constant term is 0.001, indicating that it does not have a unit root.

The unit root test results clearly show that the variables in the model have I(0) or I(1) degrees of integration (e.g. HTX tends to be I(0), while the others are I(1)). No variable is found to have I(2) degree of integration. This finding reveals that the technical condition for the applicability of the ARDL Bounds Test methodology, which is the main econometric approach of the study, is ensured.

5.2.3. Empirical Analysis Fındıngs

In this section, after confirming that I(0) and I(1) variables have a mixed degree of integration, the findings of the Autoregressive Distributed Lag Model (ARDL) approach applied to determine the short and long-run relationships between technological development and economic growth are presented. The analysis will first investigate the existence of a co-integration relationship using the F-Bounds Test, followed by diagnostic tests that test the validity and reliability of the model. Finally, the long-run equilibrium coefficients, the Error Correction Mechanism (ECM) results reflecting the short-run dynamics, and the CUSUM and CUSUMQ test results showing the stability of the model coefficients over time will be interpreted in detail.

Within the scope of the study, the model that best explains the dynamic relationship between the dependent variable ln(GDP) and the independent and control variables is determined using the Akaike Information Criterion (AIC). A total of 1458 different model variations were evaluated and ARDL(1, 1, 0, 2, 2, 2, 0, 2) model was selected as the optimum model in line with AIC's parsimony and explanatory balance principle. This model structure shows that the effect of each variable on economic growth is not only based on current period values but also on past period values. The coding of the selected model represents the optimal lag lengths of the dependent and independent variables, respectively.

The dynamic structure of the model reveals that economic growth (ln(GDP)) is significantly correlated with its own value in the previous period (p=1). In terms of technological development variables, R&D Expenditures (RD) requires 1 lag, while the Number of Resident Patents (ln(PATENT)) requires 2 lags. This implies that while the impact of R&D investments on GDP starts to be seen in a relatively shorter period of time (within one year), innovation outputs such as patents require a longer time horizon (up to two years) to affect economic growth. On the other hand, the lag-free

(0 lags) model for Medium and High Technology Exports (HTX) suggests that the impact of this variable on GDP is immediate and simultaneous.

As for the control variables, 2 lags (long-run effects) are found for Education Expenditures (EDU) and Inflation (INF), while 0 lags are found for Foreign Direct Investment (FDI). These findings suggest that the impact of FDI flows on GDP can be attributed to immediate capital inflows, whereas macroeconomic stability indicators such as education investments and inflation require a longer time period to generate their full impact on GDP. This optimal lag structure constitutes the basic equation that will be used to estimate the short-run and long-run coefficients in the subsequent analysis stages.

In order to investigate the existence of a long-run equilibrium relationship between economic growth (ln(GDP)) and technological development and control variables, Pesaran, Shin and Smith (2001) Bounds Test is applied. The test is performed over the optimum ARDL(1,1,1,0,2,2,2,0,2) model. Test results are presented in Table 5.

Table 5. F-Bounds Test Results

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	2.399461	10%	2.12	3.23
k	**6**	5%	2.45	3.61
		2.5%	2.75	3.99
		1%	3.15	4.43

The F-statistic value calculated from the model is 5.399461. The fact that the calculated F-statistic value exceeds the upper bounds (I(1)) at all standard significance levels means that the null hypothesis (H 0: no co-integration) is strongly rejected. This empirical finding conclusively proves that there is a long-run, stable co-integration relationship between technological development indicators (RD, HTX, ln(PATENT)) and economic growth (ln(GDP)) in the Turkish economy, including the effects of control variables, over the period 1995-2023. This result indicates that the preliminary assumption for estimating the long-run coefficients is satisfied.

In order for the coefficient estimates obtained in econometric analysis to be reliable and valid, the model must satisfy the basic assumptions. Diagnostic tests are critical to examine whether the error terms of the estimated model are free of autocorrelation, heteroskedasticity and specification errors. The successful passage of these tests reveals that the ARDL model is statistically robust. The results of the diagnostic tests applied to the ARDL(1, 1, 0, 2, 2, 2, 0, 2) model are presented in Table 6.

Table 6. Diagnostic Test Results

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.550931	Prob. F(14,12)	0.8568
Obs*R-squared	10.56418	Prob. Chi-Square(14)	0.7199
Scaled explained SS	1.499486	Prob. Chi-Square(14)	1.0000
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.015368	Prob. F(2,10)	0.9848
Obs*R-squared	0.082731	Prob. Chi-Square(2)	0.9595

Ramsey RESET Test			
	Value	df	Prob.
t-statistic	1.517771	11	0.1573
F-statistic	2.303630	(1, 11)	0.1573
Normality Test			
	Test Stat.		Prob.
Jarque-Bera Test Stat	2,250038		0,324646

The assumption of normality is especially important for the ability to make inferences in small samples. Accordingly, the Jarque-Bera test is used to examine whether the error terms are normally distributed. The probability value of the Jarque-Bera test is 0.3246, which is higher than the 5% significance level. This indicates that the null hypothesis that the error terms of the model are normally distributed cannot be rejected.

The presence of autocorrelation distorts the standard errors of the coefficients and leads to false inferences. Accordingly, the Breusch-Godfrey autocorrelation test is used to check whether the error terms are independent of each other (i.e., whether the error in one period affects the error in the next period). The probability value obtained for the F-statistic in the Breusch-Godfrey LM test is 0.9848. This value is much larger than all standard significance levels (e.g. 5%). Therefore, the null hypothesis cannot be rejected, suggesting that there is no serial correlation problem in the error terms of the model.

The presence of variance reduces the efficiency of the estimated coefficients. Accordingly, the heteroskedasticity test is used to check whether the variance of the error terms is constant for all observations. The probability value obtained for the F-statistic in the Breusch-Pagan-Godfrey test is 0.8568. Since this value is also high, the null hypothesis cannot be rejected. This indicates that the model satisfies the assumption of constant variance of the error terms.

The Ramsey RESET Test is used to examine whether the variables are used in the correct functional form or whether there is omitted variable bias in the model. The probability value obtained for the F-statistic of the Ramsey RESET test is 0.1573. At the 5% significance level, the null hypothesis (the model is correctly specified) cannot be rejected. This implies that the functional form of the ARDL model is correct and does not contain any significant specification error.

All the diagnostic test results obtained prove that the optimal ARDL(1, 1, 0, 2, 2, 2, 0, 2) model is robust, correctly specified and reliable in terms of econometric assumptions. The fact that the model is free from serial correlation and heteroscedasticity problems means that the estimated coefficients are efficient and consistent. These findings suggest that the long-run and short-run estimation results can be interpreted with confidence.

After proving the existence of a co-integration relationship and ensuring the validity assumptions of the model, the Long Run Coefficient Estimates obtained from the ARDL model are presented in Table 7. These coefficients reflect the permanent (long-run) effects of the independent and control variables in the model on economic growth (ln(GDP)). The long-run results show that some of our hypotheses are supported while others contradict our theoretical expectations. For a coefficient to be considered statistically significant, the probability value should generally be less than 10%, 5% or 1% significance level.

Table 7. Long Run Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RD	0.902347	1.258884	0.716784	0.0872
HTX	-0.070172	0.059485	-1.179660	0.0060
LNPATENT	-0.829390	0.993547	-0.834777	0.0002
EDU	1.498902	1.049185	1.428634	0.0786
FDI	-0.316775	0.267664	-1.183479	0.0495
INF	-0.041589	0.029036	-1.432339	0.0376

Prob < 0.10 (%10), Prob < 0.05 (%5), Prob < 0.01 (%1) indicates the level of statistical significance.

According to the results obtained, the coefficient value of R&D expenditures (RD) variable (0.9023) is positive and statistically significant at 10% significance level (Prob.=0.0872). This result supports hypothesis H2 and indicates that a 1 percentage point increase in R&D expenditures (relative to GDP) has a positive effect of approximately 0.90% on economic growth (ln(GDP)) in the long run. This is consistent with the Endogenous Growth Theory that R&D is a driver of long-run growth in Turkiye.

The coefficient value of the Medium and High Technology Exports (HTX) variable (-0.0701) is negative and statistically significant (Prob.=0.0060, 1% significance level). Contrary to our expectation, an increase in the share of high-tech exports is found to have a slightly negative effect on GDP in the long run. This unexpected result may be explained by the marginally low competitiveness of Turkiye's products in the HTX category or the limited contribution of high-tech sectors to overall economic growth.

The coefficient value of the Number of Resident Patents (ln(PATENT)) variable (-0.8293) is negative and statistically significant at the 1% significance level (Prob.=0.0002). This finding seriously contradicts our hypothesis H4. The increase in the number of patents has a negative impact on economic growth in the long run. This may indicate inefficiencies such as low commercialization rate of patents, high patent costs or the use of patents mainly to protect existing technologies.

The coefficient value of the Education Expenditures (EDU) variable (1.4989) is positive and statistically significant at the 10% significance level (Prob.=0.0786).

This result indicates that a 1 percentage point increase in education expenditures has a strong positive effect of around 1.50% on economic growth in the long run. This finding confirms the critical role of human capital in long-run growth.

The coefficient value of the Foreign Direct Investment (FDI) variable (-0.3167) is negative and statistically significant at 5% significance level (Prob.=0.0495). Contrary to the theoretical expectation, FDI is found to have a negative impact on growth in the long run. This suggests that instead of creating a technology spillover effect in the local economy, FDI may have negative consequences by crowding out local firms or concentrating only in low value-added sectors.

Finally, the coefficient value of the inflation (INF) variable (-0.0415) is negative and statistically significant at the 5% significance level (Prob.=0.0376). This finding is consistent with our expectations that high inflation impairs macroeconomic stability and hampers growth (Fischer, 1993). A 1 percentage point increase in inflation has a negative impact of approximately 0.04% on GDP in the long run.

When all the results are analyzed in general, the long-run analysis reveals that only the effect of R&D expenditures and Education expenditures on growth is consistent with our theoretical expectations (positive and significant), while other technological and control variables exhibit a negative relationship in the long run contrary to expectations.

Since the existence of a long-run co-integration relationship is confirmed, this subsection analyzes the short-run effects on economic growth and the speed of adjustment to the long-run equilibrium through the Error Correction Mechanism (ECM) model. The ECM model includes the coefficient (CointEq(-1)) that indicates how fast the imbalances caused by short-run shocks are corrected to the long-run equilibrium. ECM test results are presented in Table 8. The most critical finding of the ECM model is the coefficient of the error correction term (CointEq(-1)). Value and Significance: The coefficient of CointEq(-1) is estimated as -0.431359 and is highly statistically significant at the 1% level with a probability value of (0.0001). The fact that this coefficient is negative and significant once again confirms the existence of a long-run equilibrium relationship and indicates that short-run imbalances are corrected over time. the absolute value of this coefficient is 0.431359. This implies that about 43.14% of the short-run imbalances in economic growth (ln(GDP)) are corrected towards the long-run equilibrium within the next period (year). This speed of adjustment implies that the system is moderately resilient to short-term shocks.

Table 8. ECM Test Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	13.68701	2.242173	6.104351	0.0001
D(RD)	-0.469185	0.299337	-1.567413	0.1430
D(LNPATENT)	0.799838	0.135682	5.894940	0.0001
D(LNPATENT(-1))	0.838251	0.150557	5.567648	0.0001
D(EDU)	0.235978	0.077266	3.054118	0.0100
D(EDU(-1))	-0.670701	0.123207	-5.443690	0.0001
D(INF)	-0.003011	0.001148	-2.623035	0.0223
D(INF(-1))	0.019104	0.002839	6.728980	0.0000
CointEq(-1)*	-0.431359	0.070859	-6.087593	0.0001

Prob < 0.10 (%10), Prob < 0.05 (%5), Prob < 0.01 (%1) indicates the level of statistical significance.

The coefficients of the first differenced variables indicate the immediate or one-period lagged effects of short-run variables on GDP growth rate. According to the results, the change in the number of patents in the current period (0.7998) and one-period ago (0.8382) has a positive and highly significant effect on GDP growth. This suggests that the increase in resident innovation activities has a positive impact on the economic growth rate even in the short run.

The current period change in education expenditures (0.2359) is positive and significant, while the one-period lagged change (-0.6707) is negative and significant. This finding can be interpreted as suggesting that short-term increases in education expenditures, while initially creating a positive momentum, have the opposite effect in the following period (perhaps due to budgetary constraints or restructuring costs).

The current period change in inflation (-0.0030) has a negative and significant impact on GDP growth, while its one-period lagged change (0.0191) is positive and highly significant. This may indicate that inflation shocks slow down growth in the immediate period, but lagged mechanisms such as anti-inflationary policies or nominal income increases partially contribute to growth in the next period.

The short-run change in R&D expenditures is statistically insignificant even at the 10% significance level (Prob.=0.1430). This implies that the main and significant effect of R&D investments on growth occurs only in the long-run equilibrium relationship. Overall, the short-run dynamics suggest that patent outputs play a strong positive role on growth in both the short and long run and that the system corrects imbalances at a reasonable pace.

It is crucial for the long-run validity of the model to check whether the long-run and short-run coefficients obtained from the ARDL model are stable over time. For this purpose, Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUM of Squares - CUSUMQ) tests are applied and the results are presented in Figure 12. These tests are based on a method proposed by Brown, Durbin and Evans (1975).

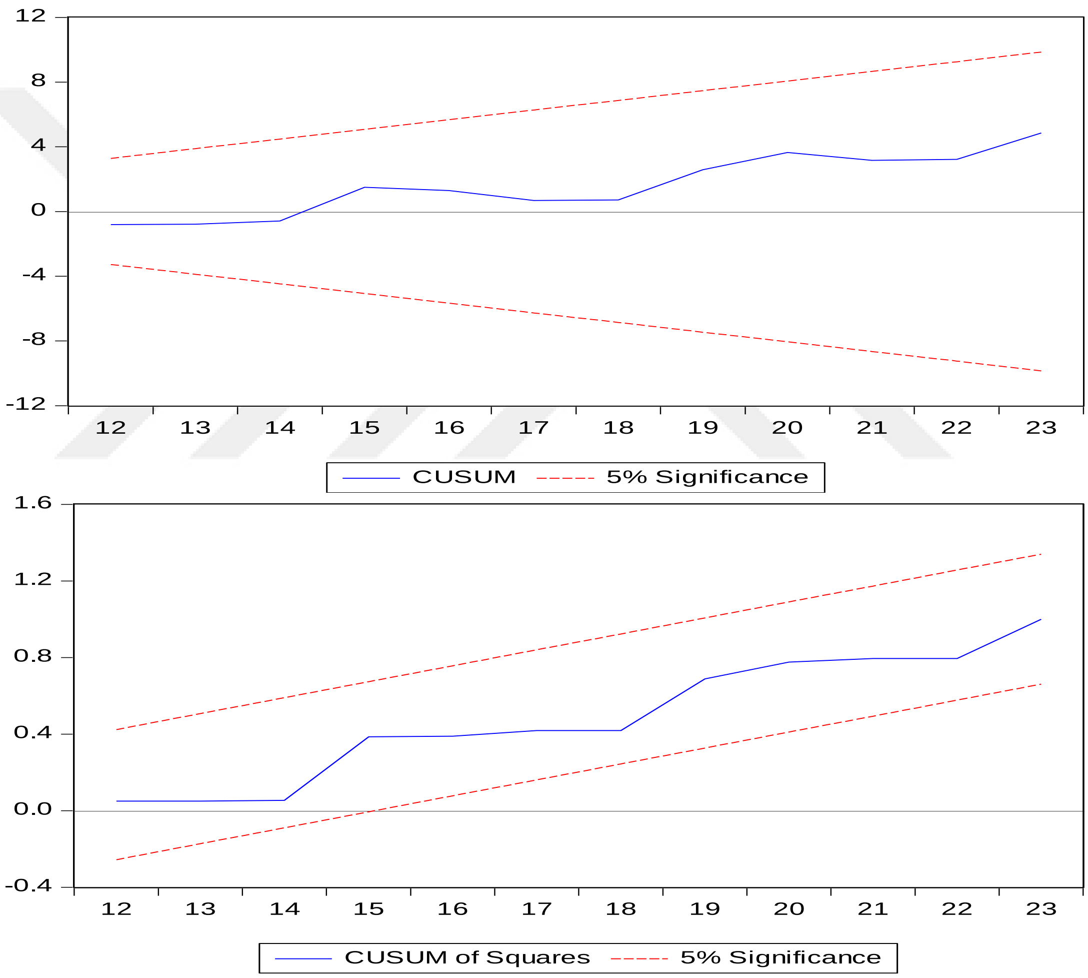


Figure 12. CUSUM and CUSUMQ Test Results

In these tests, the null hypothesis (H0) is that the coefficients of the model are stable over the entire period. If the blue line representing the test statistic falls between the critical red lines at the 5% significance level, the null hypothesis cannot be rejected and it is concluded that the coefficients of the model are stable. Accordingly, the results of the CUSUM Test in the top panel of Figure 12 show that the blue line (sum of cumulative error terms) remains within the critical red lines at the 5% significance level throughout the entire period. The test follows a course close to the zero line, especially between 2017 and 2023. This finding implies that the coefficients of the model (both the long-run and short-run coefficients) did not undergo a systematic structural break over the period analyzed and remained stable over time.

The CUSUMQ Test results presented in the bottom panel of Figure 12 test the stability of the model variance (sum of cumulative square root errors). The blue line (cumulative sum of squares) is within the critical red bounds at the 5% significance level for the entire period analyzed. This finding suggests that the model variance does not change over time, i.e. the stability of the model coefficients does not depend on a change in the variance of the errors.

The results of both CUSUM and CUSUMQ tests show that the test statistics do not exceed the 5% critical limits. Consistent with previous diagnostic tests, this strengthens the conclusion that the long-run and short-run coefficients of the estimated ARDL model are stable over the period 1995-2023 and that the model's findings are reliable.

6. CONCLUSION and SUGGESTIONS

This study undertakes the mission of providing empirical evidence for policymaking processes in this area by examining the role of technological progress in the sustainable growth journey of the Turkish economy. In contrast to traditional growth models, the Endogenous Growth Theory (Romer, 1990; Aghion & Howitt, 1992) treats technological progress as an endogenous product of the economic system rather than an exogenous factor and argues that factors such as R&D, education and innovation are the key to long-run welfare growth. For a developing economy like Turkiye, which aims to overcome the risk of middle income trap, it is a strategic imperative to analyze the interaction of these endogenous factors beyond capital and labor accumulation.

The ARDL (Lag Distributed Autoregressive Model) approach applied on annual time series data covering the period 1995-2023 has conclusively proved the existence of a long-run co-integration relationship between the variables, thus demonstrating that technological indicators and economic growth move in a long-run equilibrium. The econometric findings elucidated the nature of this equilibrium relationship and the dynamics of adjustment in the short run. The model is free from basic econometric problems such as changing variance, autocorrelation and specification errors, confirming the reliability of the findings.

The long-run results of the analysis confirmed the expected theoretical directional and statistically significant impact of the two key variables. The most important finding of the study is that R&D expenditures as a percentage of GDP have a positive and significant long-run effect on economic growth. This result is in line with the Endogenous Growth Models developed by Romer (1990) and Aghion and Howitt (1992). According to these theories, R&D triggers productivity growth by creating new knowledge (know-how). Many empirical studies on Turkiye (Uysal, 2020; Sezgin & Budak, 2022) also support this positive relationship. This finding strongly suggests that the resources allocated to R&D in Turkiye have structurally transformed into a mechanism that feeds economic growth.

The fact that education expenditures have a positive and significant effect on GDP in the long run confirms the main argument of the Human Capital Theory

(Becker, 1964). Education not only increases productivity by creating a qualified labor force, but also increases the capacity to absorb and utilize technology. The majority of studies on Turkiye (Köksel & Tecirli, 2023; Akıncı, 2017) also support this strong, positive long-run relationship.

The negative and significant effect of inflation on growth confirms the importance of macroeconomic stability emphasized by authors such as Fischer (1993). The uncertainty created by high inflation negatively affects investment and long-term planning decisions, reducing the long-term growth potential.

The most striking results of the analysis are the significant negative effects of some of the technological and control variables contrary to the theoretical expectations. The finding that the number of patents has a negative and significant long-run effect on economic growth contradicts traditional innovation output theories. Patents should theoretically stimulate innovation. This contradiction requires an in-depth discussion of the efficiency of the patent system in Turkiye. Possible explanations in the literature include the following. Patents in Turkiye are largely academic or small-scale inventions that do not translate sufficiently into large-scale industrial production and commercialization. That is, output (patents) is high, but impact (growth) is low. Patents are used for legal protection or to deter competitors (patent blocking) rather than for actual technological progress. Quality vs. Quantity: The increasing number of patents is due to small improvements in existing technologies (incremental innovation) rather than high value-added and breakthrough (radical) innovations. Some studies on Turkiye also tend to find no or weak causality between these variables.

The fact that the share of high-tech exports has a negative and significant effect in the long run contradicts the trade-based growth hypothesis (Grossman & Helpman, 1991). This finding may reflect the differences in Turkiye's export structure compared to the European Union countries. While in developed countries (HTX) generally generates a positive effect, this negative result in Turkiye can be explained by the following reasons. The HTX category is largely based on medium technology and the profit margins of these products in international competition are constantly decreasing. Import Dependence: Exports of high-tech products are highly dependent on imported intermediate goods and technology inputs. In this case, the value added of exports does not remain in the country and its contribution to GDP decreases.

The negative and significant long-run effect of FDI contradicts the expectation of technology spillover predicted by authors such as Borensztein et al. (1998). This negative effect points to critical problems with the structure of FDI in Turkiye. The fact that FDI is mostly concentrated in services (especially wholesale and retail trade) or low value-added manufacturing sectors suggests that there are insufficient flows to sectors that can lead to technology transfer and high productivity growth. Large foreign firms exclude local SMEs from the market, reducing competition and blunting the R&D efforts of local firms. The literature suggests that for some developing countries, FDI has a positive impact only above a certain human capital threshold.

The coefficient of the Error Correction Term (ECM) is negative and statistically significant, indicating that short-run imbalances are corrected towards long-run equilibrium. The adjustment rate of around 43% indicates that the economic system is able to correct about half of the shocks that occur over a one-year period, which suggests that the Turkish economy has a reasonable flexibility.

In the short run, changes in the number of patents are found to have a strong and positive impact on economic growth. This implies that instantaneous increases in resident innovation efforts contribute positively to the growth rate either in the current year or the following year. The short-run effect of R&D expenditures is found to be insignificant. This result is fully consistent with the theoretical expectations that the effects of R&D investments do not emerge immediately but with a long lag (through know-how accumulation). Inflation shocks are found to slow down growth in the short run, but have an opposite effect with a one-period lag. This suggests that the effects of anti-inflation mechanisms or monetary and fiscal policies are reflected in the system with a lag.

The empirical findings reveal the complex nature of the relationship between technological development and economic growth in the Turkish economy, and the results obtained are in strong agreement with the generally accepted theories in the national and international literature in some places, while at other points there are differences. The long-run results of our study support the basic assumptions of the Endogenous Growth Theory (Romer, 1990; Aghion & Howitt, 1992) by confirming the positive and significant effects of R&D and Education Expenditures on economic growth in the Turkish context. The positive R&D output is in line with the general literature on Turkiye (Sezgin & Budak, 2022; Uysal, 2020), which shows that this variable triggers growth. Similarly, the strong positive effect of Education Expenditures reinforces the findings of many studies in Turkiye (Köksel & Tecirli, 2023) and shows the strength of the Human Capital Theory (Becker, 1964). Moreover, the negative impact of inflation on growth is consistent with the Fischer (1993) hypothesis that macroeconomic stability is essential for investment and welfare.

Our findings differ from the general expectations in the literature on two important outputs of technological development, namely the number of resident patents, medium and high technology exports and foreign direct investment variables. The finding that increases in the number of patents and HTX have a negative and significant effect on GDP in the long run constitutes an anomaly for innovation theories. While patents generally have a positive effect as tangible evidence of technological progress in the literature, this negative finding for Turkiye points to the problem of the quality and low commercialization rate of patents rather than their quantity. This suggests inefficiencies in the innovation system, such as the inability to transform patents into high value-added products and processes, instead using them to protect existing technologies.

The negative effect of FDI is contrary to the general international literature expectation that foreign capital leads to technology spillovers. While FDI, especially in advanced economies such as the European Union countries, increases productivity by combining with strong human capital, this effect is reversed in Turkiye. This contradiction suggests that the vast majority of FDI flows to Turkiye are concentrated in services (wholesale-retail trade) or low/medium value-added manufacturing sectors rather than high-tech or R&D intensive sectors. Therefore, we conclude that the risk of FDI crowding-out local firms out outweighs the benefits of technology transfer. Similarly, the negative long-run effect of HTX indicates that Turkiye's exports are heavily dependent on imported intermediate goods and that the value added of these exports is not sufficiently retained domestically, pointing to the risk of a medium technology trap in contrast to EU countries.

By clarifying the long-run relationship between technological development and economic growth in Turkiye, this study shows the need for policymakers to implement selective and focused innovation policies. Continue R&D Investment, Patent System Reform is a Must: The positive effect of R&D input indicates that spending incentives should be maintained. However, the negative impact of the number of patents necessitates a shift from quantity to quality. The patent system needs to be reformed on the basis of commercialization success, licensing and industrial application criteria. On the other hand, the strong positive effect of education expenditures confirms that investment in human capital is Turkiye's most robust long-term growth strategy. Restructuring the education system to increase its technology absorption capacity (STEM, advanced analytical skills) is critical. In addition, the negative effects of FDI and HTX require selective incentive policies. Incentives should be directed towards high value-added, technology-intensive manufacturing and R&D-oriented projects, not just the volume of FDI. This should aim to ensure that foreign investment leads to technology spillovers through joint R&D projects with local firms, rather than local exclusion. Ultimately, the findings of our study strongly suggest that Turkiye's long-run growth depends not only on increasing the quantity of investment, but also on simultaneously improving the quality of innovation, education and foreign investment.

In a rapidly transforming global landscape, the role of technology has become increasingly vital. For countries aiming to enhance their competitiveness and achieve sustainable development, formulating and implementing robust science and technology policies has become a necessity rather than a choice.

While today's developed nations adopted and implemented science and technology strategies earlier—securing their technological leadership—countries like Turkiye, still classified as developing, have only recently begun to demonstrate awareness and commitment in this area.

Before the 1960s, Turkiye prioritized industrialization over science and technology policy. Although the shift to a planned economic model in 1960 sparked an increase in scientific and technological initiatives, these efforts were not effectively supported by techno-economic policies. If technology is recognized as a fundamental driver of production, then Turkiye's lack of progress in this domain has resulted in continued reliance on import-substitution industrialization. This approach, when analyzed in terms of scale of production, industrial structure, and the use of labor-intensive technologies, has contributed to recurring economic instability.

During the import-substitution era, although the use of technology became more widespread with state backing, Turkiye failed to establish the capacity to generate its own technological outputs. Long-term protectionist policies created a disincentive for entrepreneurial activity, weakened competitive dynamics, and fostered an industrial environment marked by monopolistic and oligopolistic tendencies characterized by high costs and profit margins.

Throughout the global technological race of the 1960s, Turkiye consistently lagged behind. While countries like the UK underwent an industrial revolution, and nations such as the US, Japan, and South Korea gained momentum through effective development strategies, Turkiye observed these transformations without achieving comparable results. Despite initiating development programs in a similar period, Turkiye was unable to match South Korea’s rapid advancements.

As a developing country, Turkiye also struggled with one of the most commonly adopted strategies for acquiring technology—technology transfer. The country was unable to build the necessary infrastructure to effectively manage and internalize transferred technologies.

Following the economic reforms of the 1980s, Turkiye began to pursue liberalization and outward-oriented industrial policies. However, the 1990s—marked by globalization and liberalized trade—represented a lost decade for the Turkish economy. Structural economic problems prevented the implementation of essential reforms. Additionally, the science and technology policies developed during this period failed to gain sufficient traction among the private sector and broader society, limiting their effectiveness.

Once a global leader in textiles, Turkiye has found itself unable to compete with countries that possess both advanced technologies and highly skilled labor forces. Today, production growth is increasingly driven not just by low-cost labor, but by the integration of cutting-edge technologies.

Unless Turkiye begins to produce the technologies it needs domestically, it will remain dependent on imported technology—an approach that does not contribute meaningfully to long-term development. In summary, to achieve sustainable growth, Turkiye must give greater importance to education in order to train a skilled workforce and must apply science and technology policies in a committed and integrated way. These efforts should be reinforced through consistent alignment with economic and political strategies.

Successful international examples highlight that prioritizing research and development (R&D) has been a decisive factor in technological progress. Having lacked consistency in this area thus far, Turkiye must now recognize the importance of R&D by increasing both its financial commitment and institutional support.

Turkiye needs to formulate and implement a science and technology policy tailored to its own context. A central element of this strategy must be enhancing collaboration among industry, government, and universities. Greater attention should be given to fostering partnerships within this "triple helix" framework. In this regard, the country should invest more in establishing and expanding technoparks and research-driven innovation hubs, which are proliferating globally, to strengthen its capacity as a technology-producing nation.

Based on the empirical findings of this study, several important suggestions can be proposed for policymakers, researchers, and future academic studies. The results indicate that technological development plays a significant role in supporting economic growth, particularly in emerging economies such as Türkiye. Therefore, strengthening technology-oriented policies should be considered a strategic priority.

First, policymakers should place greater emphasis on increasing investments in research and development (R&D). Public support mechanisms, tax incentives, and subsidies directed toward innovative firms can contribute to the diffusion of technological progress across sectors. In addition, encouraging collaboration between universities, research institutions, and the private sector may enhance knowledge transfer and improve innovation capacity.

Second, improving the quality of human capital appears to be essential for maximizing the positive effects of technology on economic growth. Policies aimed at enhancing education systems, particularly in science, technology, engineering, and mathematics (STEM) fields, should be expanded. Moreover, lifelong learning programs and vocational training can help the labor force adapt to technological change and reduce skill mismatches in the labor market.

Third, digital infrastructure development should be supported to ensure that technological advancements translate into productivity gains. Expanding access to high-speed internet, supporting digital transformation in small and medium-sized enterprises (SMEs), and promoting digital literacy can help increase overall economic efficiency and competitiveness.

From an academic perspective, future research may extend this study by incorporating alternative indicators of technological development, such as digitalization indices or innovation output measures. Additionally, comparative analyses involving different countries or regional panels could provide deeper insights into how institutional structures influence the technology–growth relationship. Employing nonlinear models or sector-based analyses may also contribute to a more comprehensive understanding of the dynamics between technology and economic growth.

In conclusion, the findings of this study suggest that technology-driven growth strategies, when supported by effective education policies and institutional frameworks, can significantly enhance long-term economic performance. These suggestions may serve as a guideline for both policymakers and researchers seeking to promote sustainable economic growth through technological advancement.

The empirical results of this study also generate important policy outcomes that are directly aligned with its theoretical framework. The underlying theory of this research is based on the assumption that technological progress functions as a key driver of economic growth by increasing productivity, improving efficiency, and enabling structural transformation within the economy. The findings empirically support this theoretical argument in the context of Türkiye.

From a policy perspective, the results suggest that technology-oriented growth strategies should not be treated as short-term economic tools, but rather as long-term structural policies. This implies that governments should design stable and consistent technology policies that go beyond cyclical economic fluctuations. In line with the theoretical framework, technology is not an isolated factor; its effectiveness depends on complementary elements such as human capital, institutional quality, and education. Therefore, technology policies should be implemented together with education and innovation-supporting institutional reforms.

Furthermore, the positive relationship observed between technological development and economic growth confirms the theoretical view that economies transitioning toward knowledge-based production structures can achieve higher and more sustainable growth rates. This outcome indicates that policy interventions aimed at fostering innovation, digital transformation, and technological diffusion can accelerate the transition from traditional production models to technology-intensive economic structures.

In theoretical terms, this study contributes to the existing literature by providing empirical evidence that supports endogenous growth theory, which emphasizes the role of technology and innovation as internal drivers of economic growth. By focusing on Türkiye, the study extends the applicability of this theoretical approach to an emerging economy context, where structural constraints and institutional characteristics may differ from developed countries. Thus, the findings reinforce the argument that technology-led growth is not exclusive to advanced economies but can also be a viable development strategy for emerging markets when supported by appropriate policies.

Overall, the policy outcomes derived from this study strengthen the theoretical proposition that sustainable economic growth can be achieved through technology-driven development strategies. This alignment between theory and empirical findings enhances the explanatory power of the research and provides a solid foundation for future policy design and academic inquiry.

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