Examining Technological Trends in Iran's Manufacturing Sector through Science and Technology Indicators

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ABSTRACT

This paper examines the technological trends in Iran's manufacturing sector over time, using the following science and technology indicators: human capital per capita from the Federal Reserve Bank of St. Louis, the ratio of research and development expenditures to gross domestic product calculated by the World Bank, the World Bank human capital index , the economic complexity index from Harvard University's Atlas of Economic Complexity, the Global Innovation Index published by the World Intellectual Property Organization, and the manufacturing competitiveness performance as calculated by UNIDO. By analyzing the developments in various science and technology indicators within Iran's manufacturing sector, it can be concluded that these indicators showed an upward trend until the late 1380s (2000s in the Gregorian calendar). Overall, both the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar) and the onset of economic sanctions, technological advancement in the manufacturing sector has stalled, leaving the Iranian economy in a relatively stagnant state, with some indicators even showing a backward movement. Despite this, given the potential of Iran's economy, appropriate policymaking could partially reverse this trend. Considering the overall findings of this article, which indicate a decline in technological activities of the manufacturing sector over the past decade, we can argue that the lack of economic stability in the manufacturing sector, and macroeconomic developments in the country, have created an unfavorable environment for Iranian industries. This situation has led entrepreneurs and industrialists to focus more on maintaining existing performance rather than pursuing innovation and increasing competitive capacity, which has hindered efforts to expand activities and capture a larger share of the global market.

KEYWORDS

Economic Complexity Index, Iran, Manufacturing Sector, Science and Technology Indicators.

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Introduction

In recent decades, serious competition in the global economy has rendered traditional economic advantages-such as cheaper energy, lower labor costs, access to natural resources, economies of scale, and mass production- insufficient for the success of a company or industry. Therefore, additional advantages are necessary to remain competitive in the global market. For example, skilled human resources, mastery of technical skills and up-to-date technologies, effective communication both at corporate and individual levels, organizational structures that foster problem-solving capabilities, and flexibility to address interdisciplinary challenges provide a stronger chance of survival in today's competitive landscape, compared to an industrial economy solely reliant on factories and physical production.

For this reason, both industrialized and emerging economies are rapidly shifting from their traditional models to knowledge-based economies. In a knowledge-based economy, knowledge and technology serve as the main engines of economic growth and development and are the key and dominant factors of production. Thus, a knowledge-based economy can be defined as one where the creation, dissemination, and utilization of knowledge are the primary sources of economic growth (Abramovitz, 1986; Nelson, 1998).

Consequently, in the current context, physical and natural resources are less important than knowledge, which has become a more significant input, alongside labor and capital, for production. Without knowledge, the creation of economic value is no longer feasible (Arundel, 2005). In other words, what distinguishes a knowledge-based economy from a resource-based economy is its greater focus on human capital, industrial property rights, and research and development as the main sources of innovative ideas, information, and new methods. In such an economy, there is a strong emphasis on an advanced service sector, driven by information technology and the digital economy (Kwon, 2009).

Thus, in a knowledge-based economy, physical capital is relegated to a secondary position, with knowledge-based assets and resources becoming the primary advantages of industries and companies. Knowledge-based capital refers to a range of non-physical assets, including in-company research, data, software, design skills, and human skills, which are now regarded as the main competitive advantages for companies. These assets enable countries and companies to dominate other industries with higher added value and greater complexity, thereby increasing their competitiveness in the global market and ultimately achieving material prosperity.

In this context, previous definitions of economic growth and development, proposed by scholars in the early decades after World War II, which defined economic development as a shift from low-productivity structures to higher productivity structures, are no longer sufficient. Today, a new body of literature, termed "economic complexity", has been introduced by scholars such as Hidalgo and Hausmann (2009). It considers a country's economic development path as being dependent on its capacity to aggregate and equip technological capabilities to produce more diverse and complex products. In other words, economies that move towards greater economic complexity are more likely to sustain economic growth. Thus, it can be argued that improving economic complexity, whether at the level of companies, economic sectors, or countries, is closely tied to mastering knowledge, fostering a knowledge-based economy, and accumulating knowledge-based capital. In fact, there is a direct relationship between economic complexity and the economic competitiveness of countries (Erkan and Yıldırım, 2015).

This indicates that the more complex an economy is, the more its sectors will rely on knowledge and technology, resulting in greater competitiveness for companies. Specifically, a firm can achieve greater success in global competition if two essential prerequisites are met: first, the overall environment in which it operates is more complex (a complex economy), and second, the firm itself has made sufficient efforts in innovation (investment in empowerment) (Besanko, et al., 2016).

Extending this concept to the manufacturing sector, it can be said that Iranian economy's manufacturing sector can also become more competitive if, first, the overall Iranian economy moves towards greater complexity, and second, sufficient investments and efforts are made within the manufacturing sector to foster innovation and knowledge enhancement. Given this framework, the present research addresses two fundamental questions: What is Iranian economy' current position on the economic complexity path? And to what extent have efforts and investments been made within manufacturing sector to promote innovation and knowledge? To answer these questions, this article examines the position and potential of the Iranian economy through the lens of knowledge and technology indicators, to clarify the environment in which Iranian manufacturing firms operate. The following section evaluates the overall status of the manufacturing sector in terms of trends in knowledge and technology indicators and provides a summary of key concepts.

Literature Review

Many studies have examined the status of countries in terms of science and technology indicators. For example, Lima et.al. (2022) demonstrated how production (manufacturing), disaggregated into sub-sectors based on research and development (R&D) intensity, affects the level of economic complexity (ECI). Wo methods were used: 1) the parametric by Panel Dynamic Ordinary Least Squares (PDOLS) and 2) the non-parametric: a) Data Envelopment Analysis (DEA) and b) Malmquist Decomposition. The econometric results suggest that the allocation of workers in the manufacture of high R&D level has a positive impact on the ECI level of all the countries in the sample analyzed, whereas in the sectors of lower R&D there is a greater impact in emerging countries, but lower effects (or negative) on advanced countries. In general, the non-parametric results present the relationship between efficiency in manufacturing subsectors and economic complexity as an inverted U shape. Special attention is given to Brazil, which manufacturing catching up was underperformed in explaining total factor productivity in the analyzed period.

Koch (2021) stated that economic complexity is typically calculated based on a country's gross export structure. However, when global value chains become more integrated, gross exports may present a misleading picture of a country's economic performance. According to the findings of Sokolo-Maldanovic et al.'s (2016) research, which is based on a new empirical approach, economic complexity is approximated using a country's value-added export structure. They also confirmed the positive impact of innovation and the production of technical knowledge on economic or productivity growth.

Javadi (2023) examined the development trends of medium and advanced technologies and Iran's global standing from 1990 (1369) to 2020 (1399), using data from the United Nations Industrial Development Organization (UNIDO) and the 2022 Industrial Competitiveness Performance Index report. Overall, Iran ranks 73rd out of 154 countries in terms of the share of medium and advanced technology exports in total industrial exports, with countries like Turkey (55) and India (61) holding better positions.

An analysis of the industrial competitiveness index indicates that although one of its sub-indices, titled "Deepening and Upgrading Technology" (the share of value added from medium and advanced technology products in Iran's industrial value added), improved between 1990 and 2010, reaching 45%, it remained stable from 2011 to 2020. Additionally, in 2020, over 54% of Iran's industrial exports consisted of raw and semi-raw products, with only about 0.5% being advanced technology products, and approximately 32.5% being medium technology products. Thus, it can be concluded that Iran is heavily reliant on raw and semi-raw material export, and advanced technologies have a minimal contribution to its exports.

Yaghoubi Manzari et al. (2022) examined the impact of product complexity on participation in global value chains among the member countries of the Organization of Islamic Cooperation (OIC), using a generalized method of moments model. The estimation was conducted using panel and time series data of 56 Islamic countries from 2008 to 2018, and employed the generalized method of moments and ordinary least squares techniques.

The results indicated that increasing product complexity in Islamic countries enhances their participation in global value chains. Additionally, "technology absorption index" and "share of R&D expenditures" were confirmed to significantly impact participation in global value chains. Therefore, based on the existing capacities and research findings, Yaghoubi Manzari et al. (2022) recommend that the investigated countries prioritize their programs to increase participation in global value chains by focusing on complexity and product development (through diversification and quality enhancement), technology absorption and competitiveness, enhancing horizontal and vertical collaborations for technology development, creating technology exchange networks, improving R&D activities through the alignment of industrial and trade policies, and providing the necessary conditions for improving human capital development policies and investment development.

Samandar Ali Eshtahardi et al. (2020) investigated the causal relationship between the components of a knowledge-based economy and the economic complexity index. For this purpose, the panel data of 113 countries from 2006 to 2016 were examined. The fourteen variables introduced by the World Bank were used to represent the axes of knowledge-based economy. Through principal component analysis, these axes were condescended into four components. Then, the Granger causality relationship between these components and the economic complexity index, as well as the reverse, was examined.

The findings suggest a bidirectional causal relationship between education, information and communication technology, and economic institution with economic complexity, as well as a unidirectional causal relationship from innovation to economic complexity. Additionally, the results show different outcomes in these causal relationships for OECD-member and non-member countries.

Afshin and Azadari (2019) conducted a study for the Research Center of the Parliament to analyze Iran's industrial competitiveness performance in comparison to regional and selected global countries. The research employed a statistical analysis methodology based on UNIDO time series data. The statistical population included the industrial sector or manufacturing industries, and the statistical base covered the long-term period from 1990 to 2017. The findings indicated that Iran's industrial competitiveness performance (CIP) in 2017 (1396) ranked 49th among 150 countries worldwide, with a score of 0.062, showing an improvement from its 53rd rank in 2016. According to the UNIDO report, over 65% of Iran's industrial products in 1396 were resource-based (RB). Medium technology products (MT) accounted for approximately 25.5%, while high technology products (HT) accounted for about 0.9%, indicating a significant challenge for Iran's industrial products in terms of enhancing competitiveness in global markets .

In the long-term analysis of industrial competitiveness performance indicators from 1990 to 2017, the findings suggest that Iran's industrial development is relatively good, but, compared to various countries worldwide, it has regressed. Although the role of Iran's industrial sector in the international arena has generally increased, due to sanctions and external conditions such as the post-JC POA environment, some fluctuations are observed. The analysis of industrialization intensity indicators shows that the third development plan, starting in 1379 and continuing with ups and downs in subsequent years, was a turning point for industrial development in Iran. However, over the past decade, due to various reasons, including consecutive negative growth rates and negative capital formation, the industrial sector's share of Iran's GDP has declined to about 12.5%. This situation is a wake-up call for industrial policymakers, emphasizing the need to gain the private sector's trust, strengthen capital formation, and remove production barriers to enhance the role of this sector in Iran's economy.

Shahmoradi et al. (2018) examined Iran's technological competitiveness in comparison to the countries outlined in the Vision Document over a ten-year period. They sought to assess Iran's competitiveness in technological products compared to regional countries and to identify its main competitors using the economic complexity approach.

The findings, based on the four-digit codes of the Harmonized System, indicate that two products—profile bars and wires made from artificial wax and ready-made wax—exhibit the highest complexity, in which Iran has competitive power with no regional rivals. In classifying countries based on economic complexity, Iran falls into the lowest class, while in classifying products based on economic complexity, most of Iran's competitive products fall into the second-lowest class.

The findings also suggest that although the occupied Palestinian territories have the highest economic complexity and the greatest diversity of complex products in the region, they are not considered Iran's main competitors in competitive technological products. Meanwhile, Iran shares the most technological overlap with Egypt and Turkey, which are considered its main competitors in the region.

Methodology

Knowledge and technology are the most important factors of production in today's world, essential for achieving success in competition and gaining a share of the global market. Given that Iran's manufacturing sector is a subset of the broader economy, the structure of knowledge creation and dissemination, and its role in Iran's economy directly influences the manufacturing sector and its success in technological competition. Therefore, this issue will be examined by analyzing the status of the Iranian economy through key science and technology indicators.

One of the fundamental components of science and technology indicators is the status of human resources and human capital in each country. As emphasized in the literature on economic growth and supported by empirical studies, one of the main drivers of economic growth is human capital. Although human capital is often defined as the average years of education within a country's population, this definition overlooks some important theoretical and empirical dimensions. In economic growth theories, both the investments individuals make in accumulating human capital and the returns of these investments are significant. Therefore, it is necessary to adopt a comprehensive approach when examining and calculating the indicators of this topic (Acemoglu, 2009)

One of the most comprehensive indicators of human capital is the human capital index per individual (Feenstra et al., 2015). This index consists of two main components: the average years of education, as measured using Bro and Lee's (2013) methodology, and the returns to education, as determined by Psacharopoulos's (1994) methodology. The returns to education refer to the extent to which education has influenced productivity within the economy. This brings into focus the quality of education and its alignment with the economy's needs. In other words, if education has led to an increase in economic productivity, it signifies an enhancement in the country's human resources.

Another indicator used to assess human capital across countries is the Human Capital Index (HCI), calculated by the World Bank[1]. This index measures the development and

1. For more details, please refer to the link below on the World Bank website.
http://databank.worldbank.org/data/source/human-capital-index

nurturing of human capital and the extent to which individuals' potential is utilized in different countries.

In fact, this index addresses the extent to which newborns have access to health and educational facilities, and how much they can contribute to the organization they work for in the future[1].

One of the indicators that reflects a country's investment in knowledge enhancement is the ratio of research and development expenditures to its gross domestic product (GDP). To assess Iran's status in terms of science and technology, the Economic Complexity Index (ECI) can be used (Samandral & Eshtahardi, 2020). The core idea of this index is that economic development depends on the accumulation of knowledge and its increased utilization in producing more complex goods and services[2].

In fact, the more diverse a country's produced goods are (increased diversity) and the more complex its exported goods become, the higher its economic complexity will be. In other words, the greater the diversity of a country's export products and the more unique goods it can produce—goods that fewer countries can produce—the more complex its economy becomes.

One of the indicators of countries' science and technology is the Global Innovation Index. This index consists of 81 sub-variables that are classified into two main sub-indices, namely innovation input and innovation output. The Global Innovation Index is the average of these two main indices (Javadi, 2022). The innovation input sub-index includes the following five main pillars: Quality of institutions, Human and research capital, Quality of infrastructure, Market sophistication, and Business sophistication, each receiving a score between zero and 100.

Furthermore, to examine the role and position of medium and high-tech industries in the manufacturing sector, the manufacturing competitiveness performance is analyzed. This index, used by UNIDO (United Nations Industrial Development Organization), evaluates the competitiveness and industrial performance of various economies. It includes a set of related sub-indices, utilized to assess the production and export capacity of manufactures in an economy and compare it with other countries. This index reflects countries' capacity to participate in domestic and international markets and engage in high value-added activities with superior technology. A country's competitiveness in industrial production is measured on a scale from zero to one. The closer this number is to one, the greater the country is in industrial competitiveness (Afshin and Azadari, 2019)

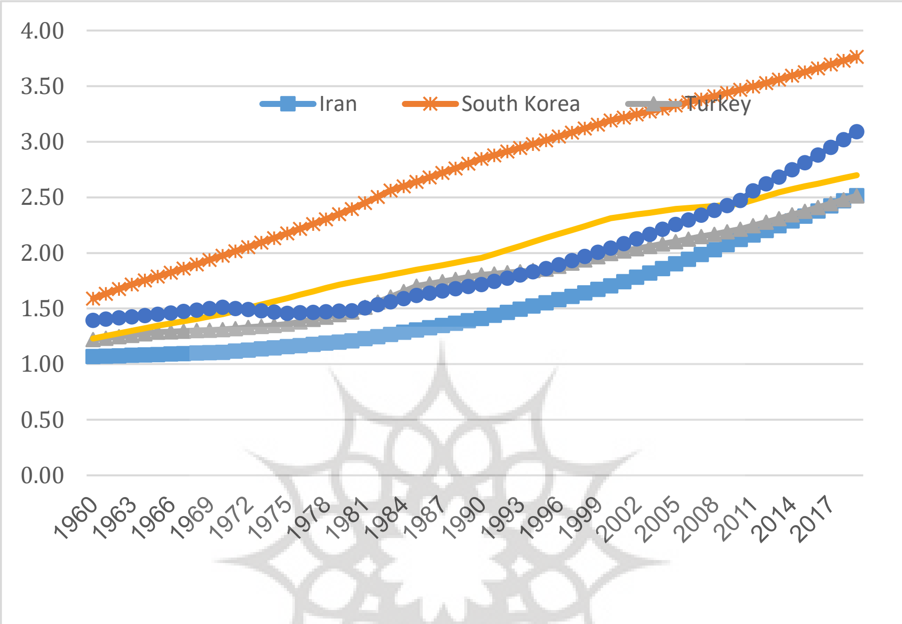
Findings

The trend of human capital for Iran and selected countries shows that in Iran human capital has been gradually increasing over time. However, its level significantly lags

1. https://www.bishtarazyek.com/the-human-capital-index/
2. More information regarding this indicator, its definitions, calculation methods, and the status of countries and industries is available on the Harvard University Atlas of Economic Complexity website at the following address. https://atlas.cid.harvard.edu/glossary

behind that of prominent developing countries, such as South Korea, China, and Brazil, that are successful in achieving economic growth. Nevertheless, in recent years, Iran's human capital trend has become closer to that of Turkey, and Iran has even shown a better status than Turkey (see Figure 1).

Figure 1.
The Human Capital Index per Person Comparison Between Iran and Selected Countries

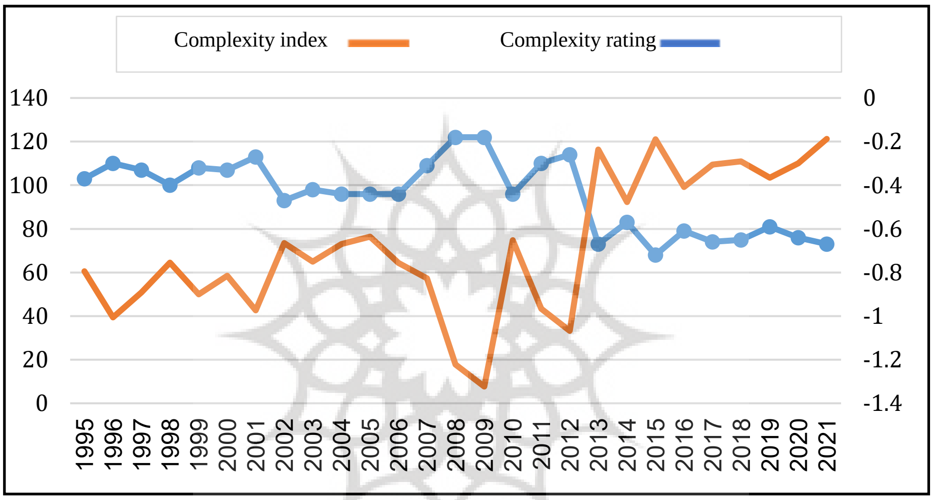


(Source: https://fred.stlouisfed.org/series)

According to the latest the Human Capital Index calculation in 2020, Iran's index value is 0.59, which is approximately equal to the global average of 0.60. In this regard, Iran's status is better than countries like India (0.49), Iraq (0.41), Kuwait (0.56), Indonesia (0.54), and Egypt (0.49). However, compared to countries like Oman (0.61), China (0.65), Russia (0.68), Vietnam (0.69), and the UAE (0.67), a significant gap exists between Iran and these countries. The top country in this ranking is Singapore, with an index value of 0.88, followed by Hong Kong, Japan, and South Korea. Overall, Iran's human capital status is at a global average level, but it seems that appropriate policies could improve its status. Given the significant investment made in public education and the expansion of universities over the past decades, an important question arises: why has Iran not yet reached the level of human capital seen in countries like China, South Korea, Singapore, and Brazil? It appears that factors such as the return on education, the quality of education, and the structure of educational system need to be analyzed to answer this question.

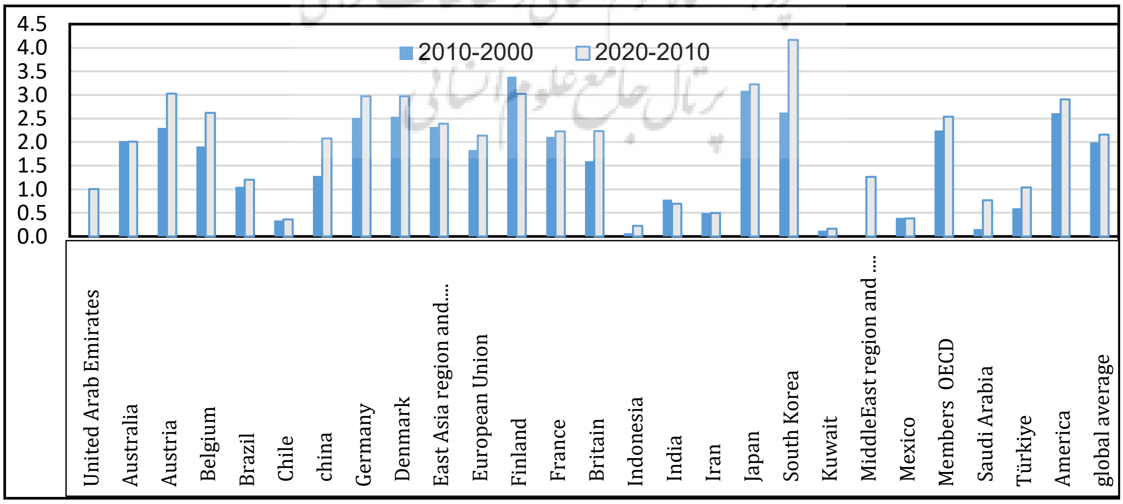
In the above Figure, the ratio of research and development expenditure to the gross domestic product (GDP) of countries is presented as an average over a 20-year period. Accordingly, Iran's investment in research and development, averaging 0.5%, lags far behind the global average (2.1%) and many developing countries such as the UAE, Turkey, China, Brazil, and Singapore. Although Iran's situation is better than that of countries like Indonesia, Mexico, Chile, and Kuwait, it is not comparable to countries like India, South Korea, or even the average of countries in the Middle East and North Africa. Among Iran’s neighboring countries, Saudi Arabia, the UAE, and Turkey have improved their status by increasing their research and development expenditures significantly from 2010 to 2020, which is expected to lead to economic success and increased competitiveness in the region in the coming years. Overall, it can be said that, there is a significant gap between Iran's investment in the production of knowledge and new technologies and the global average.

Figure 2.
The Ratio of Research and Development Expenditures to Gross Domestic Product (Average for the Years 2000-2010 (Bold) and 2010 to 2020 (Light))



(Source: World Bank)

Figure 3.
The Trend of the Economic Complexity Index (Right Vertical Axis) and Iran's Ranking (Left Vertical Axis) Over Time



(Source: Harvard University Economic Complexity Atlas)

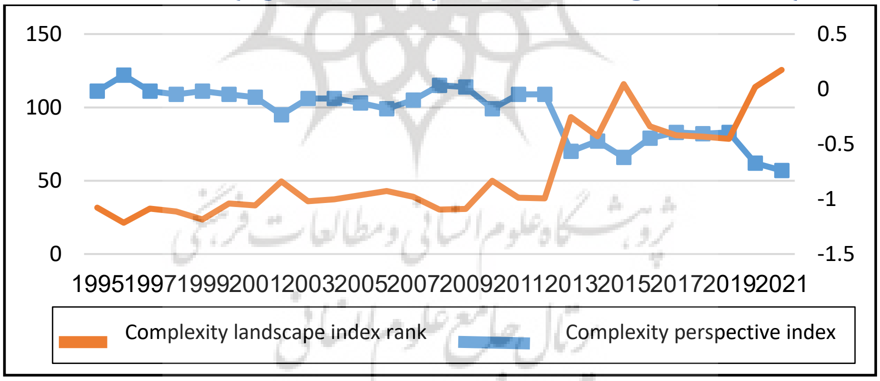
As shown in Figure 3, the value of Iran’s Economic Complexity Index (orange) has increased over the past decade. In 2021, Iran's economic complexity ranking (blue) was

73 out of 133 countries, which is a relatively acceptable rank. Additionally, this index has shown an upward trend in recent years, leading to a six-place improvement in Iran's ranking from 2016 to 2021. Overall, Iran's status in terms of the Economic Complexity Index, like its the Human Capital Index, is around the global average, positioning Iran at a medium-level in this regard.

Despite this, it seems that the Iranian economy has greater potentials than what is currently observed, which could be utilized better. This is also reflected in the Complexity Outlook Index (COI), a measure indicating how many complex goods are accessible in the current economic complexity of a country. In other words, COI shows how many complex goods are available based on the level of complexity that an economy can potentially achieve. In fact, a higher value of this index indicates abundance greater number of complex products that can be produced with a country's existing capabilities under current conditions.

As shown in Figure 4, the value of this index for Iran has increased over time and Iran's ranking in this index has also improved. This indicates that Iran, especially in recent years, has had the potential to produce and export more complex goods using its existing economic and technical capabilities. However, it should be noted that this progress cannot be sustained in the long term without making appropriate investments in science and technology and making Iran's economic environment more conducive.

Figure 4.
The Complexity Outlook Index of Iran (Right Vertical Axis) and Iran's Ranking in This Index (Left Vertical Axis)



(Source: Harvard University Economic Complexity Atlas)

Table 1 shows Iran's score and ranking in the Global Innovation Index and its sub-indices[1]. According to the 2023 Global Innovation Index, Iran has a score of 30.1 and ranks 62nd among 132 countries, which is not favorable considering Iran's potential and capabilities[2]. As indicated in Table 1, Iran's status in institutional quality (rank 131) and infrastructure quality (rank 97) is very low, suggesting that its institutions and infrastructure are not adequately aligned to support innovation. Additionally, Iran ranks very low in business complexity (rank 117), indicating that its businesses do not have much complexity, and

1. The green row indicates the score, while the white row represents the rank.
2. World Intellectual Property Organization (WIPO), "Global Innovation Index 2023: Innovation in the face of uncertainty," Geneva: WIPO. DOI:10/34667/tind.48220.

therefore, innovation does not play a significant or suitable role within them. Overall, the inputs for innovation in Iran are in a poor state, which could lead to high costs for the Iranian economy in terms of long-term competitiveness.

Table 1.
Iran's score and ranking in the Global Innovation Index and its sub-indices

Global Innovation Index						
30.1						
62						
Innovation Output	**Innovation Input**					
48	87					
Creative Outputs	**Outputs of Knowledge and Technology**	**Business Complexity**	**Market Complexity**	**Infrastructure**	**Human Capital and Research**	**Institutions**
33.1	25.9	17.7	52.9	29.3	32.6	20.6
43	55	117	19	97	60	131
Intangible Assets	**Creation of Knowledge**	**Knowledge Workers**	**Credibility**	**Information and Communication Technology**	**Education**	**Political Environment**
55.7	32.0	18.8	27.7	51.2	41.5	15.2
13	29	102	70	97	96	127
Creative Goods and Services	**Effects of Knowledge**	**Innovation Links**	**Investment**	**Public Infrastructures**	**Higher Education**	**Legal Environment**
4.3	35.2	11.4	83.3	25.0	41.8	38.0
90	40	113	3[1]	74	31	121
Online Creativity	**Dissemination of Knowledge**	**Knowledge Acquisition**	**Business, Diversification, and Market Scale**	**Environmental Sustainability**	**Research and Development**	**Business Environment**
16.8	10.5	22.9	47.8	11.8	14.5	8.7
86	107	116	90	120	49	128

(Source: Researcher's Findings)

Examining some of the sub-pillars under the main pillars of the Global Innovation Index reveals Iran's position regarding innovation and knowledge metrics on a global scale. This section analyzes the sub-pillar of research and development under the main pillar of human capital and research, as well as the sub-pillars of knowledge workers, innovation links, knowledge absorption, knowledge creation, knowledge impact, and knowledge dissemination under the main pillar of business complexity. Additionally, the sub-pillar of intangible assets under the main pillar of creative outputs is analyzed. The aim is to select the sub-pillars that are most closely connected to the technology and innovation environment.

1. The minimum coverage reported in the World Intellectual Property Organization (WIPO) (2023) Global Innovation Index has not been met.

Table 2.
Iran's Ranking in Terms of Subcomponents of the Global Innovation Index and Sub-indices

Title	2015	2020	2021	2022	2023
Subsection of Research and Development	59	48	48	47	49
Ratio of full-time researchers to the population (per one million people)	54	44	44	47	45
Ratio of gross research and development expenditures to gross domestic product	46	44	45	45	46
Average expenditure of the top three global companies in research and development		42	41	38	40
Average score of the top three universities based on global university rankings	56	44	44	43	44
Subsection of Knowledge Workers	109	103	104	97	102
Knowledge-based employment	90	77	80	78	76
Ratio of companies with formal training programs for employees	n/a	n/a	n/a	n/a	n/a
Ratio of research and development expenditures conducted by businesses to gross domestic product	64	50	53	53	53
Research and development expenditures funded by business enterprises to total research and development expenditures	48	n/a	n/a	n/a	n/a
Ratio of employed women with higher education	n/a	n/a	80	83	85
Subsection of Innovation Links	107	100	102	107	113
Collaborative research between universities and industry	99	117	120	121	124
Cluster development	94	88	87	81	87
Research and development expenditures funded from abroad	n/a	n/a	n/a	n/a	n/a
Joint investment contracts	89	122	127	129	126
Ratio of registered patents to GDP	107	64	74	86	85
Subsection of Knowledge Absorption	137	99	117	119	116
Payment of intellectual property rights (royalties)	90	94	97	95	89
Import of advanced technology	111	92	119	117	114
Import of ICT services	86	101	107	113	96
Foreign direct investment (net inflow)	116	119	110	109	112
Research talents in businesses		56	55	54	54
Subsection of Knowledge Creation	24	25	14	20	29
Resident patent applications	8	14	7	10	13
Global patent applications	n/a	53	44	40	41
Utility model applications	n/a	n/a	n/a	n/a	n/a
Publication of scientific and technical articles	40	21	11	15	27
"H" index of citable publications	44	40	40	39	40
Subsection of Knowledge Impact	114	86	85	65	40
Labor productivity growth rate	114	115	119	67	82
Rate of new business density	n/a	101	101	90	48
Total expenditure on computer software	55	58	38	30	16
Products with advanced technology	28	26	28	29	44
Subsection of Knowledge Dissemination	135	117	119	103	107
Revenues from intellectual property	92	86	95	90	88
Complexity of production and exports	n/a	n/a	100	78	84
Exports of advanced technology as a percentage of total trade	75	90	117	111	109
Exports of ICT services	114	92	125	127	122
ISO 9001 quality certifications	93	96	87	94	108
Subsection of Intangible Assets	113	13	13	10	13
Intangible asset intensity	n/a	n/a	n/a	n/a	n/a
Trademark registration applications	65	1	1	1	1
Global brand value	n/a	78	78	76	73
Industrial designs	n/a	14	4	6	11
Adaptation of organizational and ICT models	108	92	92	n/a	n/a

(Source: Global Innovation Index, WIPO, 2015, 2020, 2021, 2022 & 2023)

In 2023, Iran ranked 49th in the Research and Development subsection. The rankings of the indicators, including the ratio of full-time researchers to the population (per one million people), the ratio of gross research and development expenditures to gross domestic product, the average expenditure of the top three global companies in research and development, and the average score of the top three universities based on global university rankings, fall within the range of 40 to 46. These rankings indicate a moderate position for Iran compared to other countries worldwide.

In 2023, Iran's rank in the Knowledge Workers subsection has worsened compared to the previous year. Since the ranks reflect comparisons between countries, this decline indicates that other countries have outperformed Iran and obtained higher scores. The decrease in Iran's score in this subsection is partly due to a reduction in knowledge-based employment and partly due to a lack of data on the amount of research and development expenditures funded by business enterprises during the studied years. The indicator for knowledge-based employment, which reflects the percentage of employment in knowledge-intensive services relative to the labor force, along with the indicator for the ratio of employed women with higher education, shows Iran's poor ranking in 2023 (76 and 85, respectively).

In 2023, Iran ranked 113th in the Innovation Links subsection which is not favorable compared to other subsections. The indicator for collaborative research between universities and industry, which examines collaboration between businesses and universities in research and development, has decreased in 2023. The trend of this indicator shows that Iran performs poorly in joint research and development between universities and industries, with a decline observed each year. The cluster development indicator is derived from the average response to the following survey question: "In your country, how extensive are developed and deep clusters (geographical concentration of companies, suppliers, producers of related products and services, and specialized institutions in a specific field)?" While this indicator has improved during the studied period compared to 2015, Iran's rank has worsened compared to 2022.

The indicator for joint investment contracts, which reflects the average number of joint investment/strategic alliance contracts per billion dollars of gross domestic product over three years, highlights Iran's significant weaknesses in joint innovation investment. Additionally, Iran's poor ranking in the indicator for registered patents to GDP reflects weaknesses in international patent registration, reducing international innovation links and negatively impacting the innovation index.

Iran's ranking in the Knowledge Absorption subsection, the under business complexity main section, has improved compared to 2022. The indicator for advanced technology imports as a percentage of total trade, as well as the indicator for ICT services imports- including telecommunications, computer, and information services- as a percentage of total foreign trade has improved in 2023 compared to the previous year. However, the indicator of foreign direct investment has worsened, and Iran's ranking compared to other countries is unfavorable.

In the Knowledge Creation subsection, part of the knowledge and technology outputs main section, Iran's performance is relatively well compared to its rival countries, ranking 29th in 2023. Additionally, in the Knowledge Impact subsection, under the broader knowledge and technology outputs section, Iran holds a relatively good position with a rank of 40 in 2023. However, Iran's ranking in the indicator for labor productivity growth, which measures the average growth rate of real gross domestic product per employed person over the last three years, has been significantly inadequate during the studied years. It is important to note that factors such as international sanctions and the contributions of the oil sector have significantly affected this variable. In this context, sanctions have been a major limiting factor, halting technological advancement of Iran's industrial sector. On one hand, sanctions have reduced national revenues. On the other hand, they have increased the political and economic risks, which in turn reduce the opportunities for investing in technology within the country.

Furthermore, the indicators for Knowledge Dissemination subsection, within the knowledge and technology outputs main section, is unfavorable for Iran. In 2023, Iran ranked 109th in advanced technology exports and 122nd in ICT services exports, which include telecommunications, computer, and information services as a percentage of total trade, reflecting its poor position compared to other countries. Additionally, the indicator for production and export complexity- measured by the Economic Complexity Index, which ranks countries based on the diversity and complexity of their export baskets- shows that economies with high complexity possess a wide range of complex and specialized capabilities, enabling them to produce a wide array of complex products. Iran's rank in this indicator is 84th in 2023.

Iran's ranking in the Intangible Assets subsection, part of creative outputs section, is favorable, placing13th in 2023. Specifically, Iran ranks very well in the indicator for trademark registration applications, which reflects the number of resident trademark applications filed in national or specific regional offices per billion dollars of real gross domestic product. However, Iran's position in the global brand value indicator, measuring the total value of global brands (among the top 5000 brands) as a percentage of gross domestic product, is not favorable, ranking 73rd in 2023. In contrast, in the indicator for industrial designs, reflecting the number of designs registered in a national or specific regional office per billion dollars of GDP (PPP), Iran performs very well, ranking 11th in 2023.

Overall, the assessment of global innovation indicators places Iran's economy at an average level on the global scale. However, Iran requires more attention and effort to ensure it keeps pace with the trends set by countries in the Middle East, North Africa, and successful developing countries. Given that the present research focuses on the quality of the operational environment of industrial enterprises from the perspective of knowledge and technology, it can be concluded that the current state of Iran's economy in this regard is at an average level. Therefore, to enhance the competitiveness of industrial enterprises, more efforts are needed to improve and elevate the quality of the knowledge-based economy.

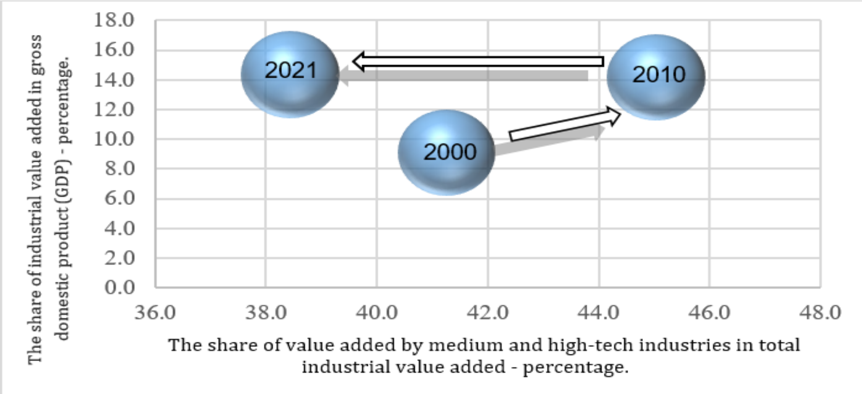
Analysis of the Structure and Developments of the Manufacturing Sector from the Perspective of Science and Technology

One of the most important questions is “to what extent the production structure of Iran's manufacturing sector is intertwined with science and technology?” This issue can be examined by analyzing the production structure of Iran’s manufacturing products in the selected years of 2000, 2010, and 2021 from a technological perspective. In Figure 5, the vertical axis represents the manufacturing sector's value-added share in the gross domestic product (GDP) (manufacturing sector’s share in economy), while the horizontal axis indicates the value-added share of medium and advanced technology industries within the manufacturing sector. Therefore, to move rightward over time in this Figure, Iran’s manufacturing production structure requires to incorporate more technology and knowledge.

However, examining this Figure in the selected years reveals two completely opposite trends. Between 2000 and 2010, a rightward and upward movement is observed, suggesting that manufacturing sector’s share in Iran's economy has increased (vertical movement) and medium and advanced technology industries’ share in the total manufacturing sector has grown (horizontal movement). Specifically, the value-added share of Iran's manufacturing products relative to GDP has increased from 9.1% in 2000 to 14.2% in 2010, and the value-added share of medium and advanced technology products in the total value added of the manufacturing sector (horizontal axis) also rose from about 41% in 2000 to 45% in 2010. This trend is indicative of an increase in the importance of the manufacturing sector in Iran's economy, with a growing focus on medium- and higher- technology industries.

However, from 2010 to 2021, this trend has been completely reversed from science and technology perspective, indicating the second trend. Specifically, during these years, the share of medium- and higher-technology industries in the total value added of the industry decreased from 45% to about 38%. This not only erases the achievements of the previous decade, but also exacerbates the situation. Meanwhile, the manufacturing sector’s share in Iran's total economy has remained almost constant at around 14% (vertical axis). In other words, it can be concluded that lower-technology industries have replaced medium-and higher-technology industries in the structure of Iran’s manufacturing sector. Based on the points made in the previous section about the importance of science and technology in competitiveness in today's world, we can argue that since Iran's economy is following a reverse trend, it leads to a loss of share in the global economy and a decrease in long-term growth in the coming years.

Figure 5.
Changes in the Structure of Industrial Product Production in Iran

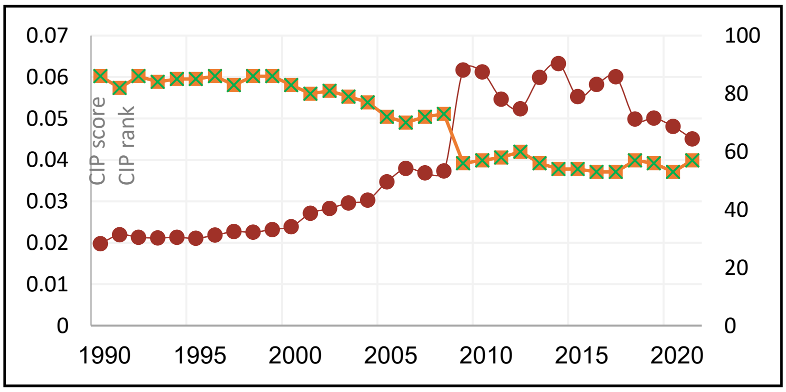


(Source: Calculations based on data from the UNIDO Database: CIP - Competitive Industrial Performance Index)

Figure 6 presents the trends of various Competitive Industrial Performance (CIP) indicators for the Iranian economy from 1990 to 2021, highlighting the developments of this index and its related sub-indices. As shown, Iran's Competitive Industrial Performance index sharply increased with the onset of the Western financial crisis in 2009, rising from rank 73 in 2008 to rank 56 in 2009. However, due to the intensification of Western sanctions from 2009 to 2012 the index declined. It observed some improvements during the following years due to the better post-JCPOA environment and the easing of sanctions. However, after 2018, with the re-escalation of economic sanctions, Iran's industrial competitiveness index again experienced a significant decline.

Although Iran's industrial competitiveness index improved in some years over the past decades, its rank shows an overall downward trend over these three decades. This indicates that, despite improvements in this index in certain years, Iran's economy is losing its position in terms of industrial competitiveness due to the better performance of other countries. In addition to the adverse effects of economic sanctions, inappropriate industrial policies have also exacerbated this situation, as the decline in industrial competitiveness rank is not limited to the years of economic sanctions and has persisted during years without significant sanctions.

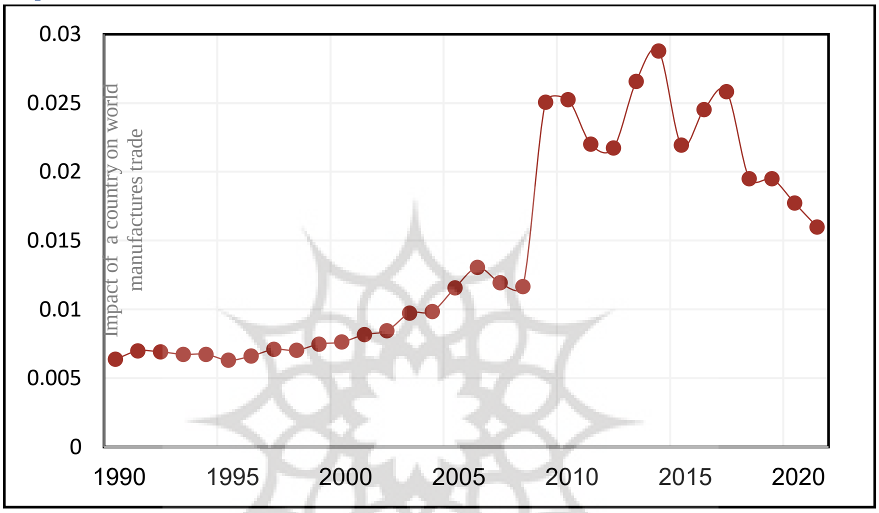
Figure 6.
Trends and Rankings of Iran's Industrial Competitiveness Index from 1990 to 2021



(Source: UNIDO Database: CIP- Competitive Industrial Performance Index

One of the indicators that reflects the level of industrial competitiveness is the Iran's impact on global industrial trade index, which is shown in Figure (7). This index reflects Iran's influence on global industrial trade and its relative competitiveness compared to other countries in international markets. According to this index, Iran's role in global industrial trade has been minimal during all the examined years, as this index peaked just over 0.28% in 2014. Since 2017, this index has shown a continuous downward trend, indicating that the role of Iran's industrial sector in global industrial trade has been declining in recent years.

Figure 7.
Trends of Iran's Impact on Global Industrial Trade from 1990 to 2021

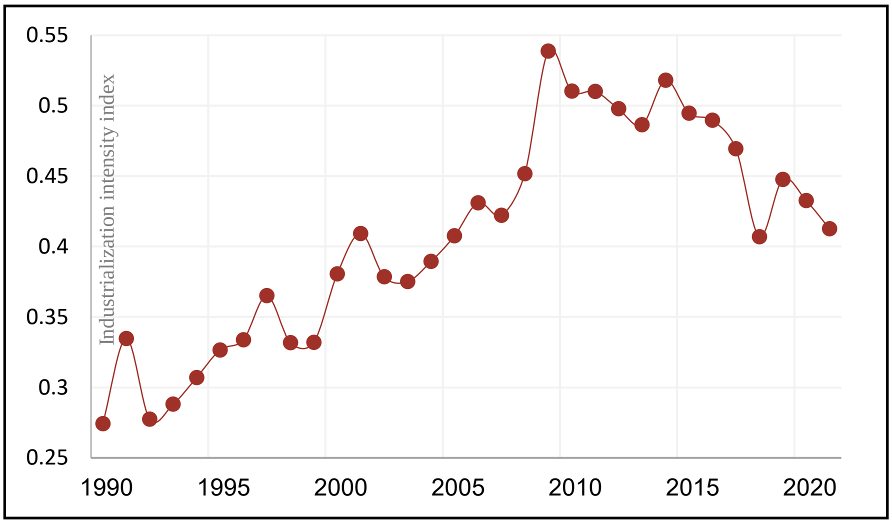


(Source: UNIDO Database: CIP - Competitive Industrial Performance Index)

Another important indicator for analyzing Iran's industrial sector is the Industrialization Intensity Index, which reflects the level of industrialization in a country (Figure 8). This index is measured based on the simple average of the share of industrial value added in gross domestic product (GDP) and the share of medium-and advanced-technology (MHT) activities within industrial value added, calculated on a scale from 0 to 100.

An examination of this index reveals two distinct trends over the past three decades. From 1990 to 2009, this index shows an upward trend, indicating that Iran's industrial sector has gained a larger share of its economy and the share of advanced-technology activities has also been increasing. This period can be interpreted as the industrialization phase of Iran's economy. In contrast, from 2009 onwards, this index has been on a downward trajectory, with a significant decline occurring after 2014, reaching its lowest point in 2018 with the onset of international sanctions.

Figure 8.
Industrialization Intensity Index of Iran from 1990 to 2021

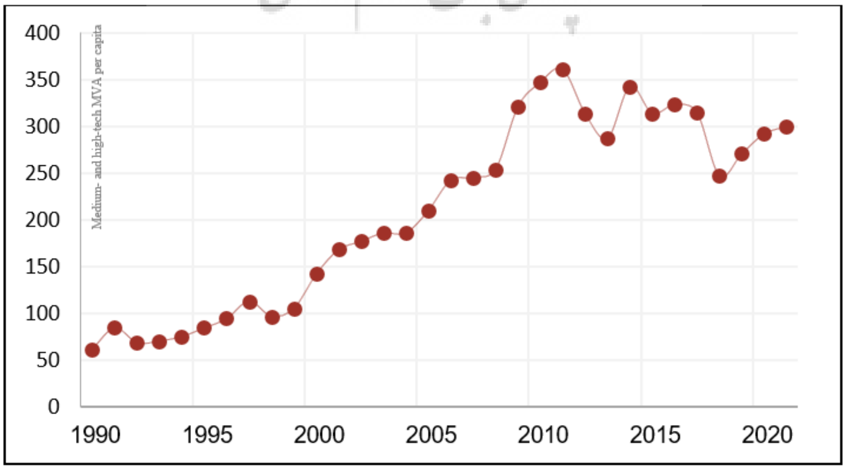


(Source: UNIDO Database: CIP - Competitive Industrial Performance Index)

Figure 9 shows the per capita value added of medium- and advanced-technology industries in Iran, which measures of the level of technological complexity in the country's industrial production compared to its potential human resources. As with the previous Figures, two trends can be observed. From 1990 to 2011, the index exhibits an upward trend, indicating that the technological complexity of Iran's industrial sector productions has been increasing in line with its human resource capacities. During this period, the per capita value added of medium- and advanced-technology industries rose from $62 in 1990 to approximately $361 in 2011, representing a significant and favorable increase.

However, after 2011, the upward movement of this index stalled, with fluctuations until 2018, when the per capita value added of medium- and advanced-technology industries decreased to $247. Although a mild upward trend can be observed after 2018 until 2021, raising the index to $300, it has not reached its 2011 level after a decade.

Figure 9.
Per Capita Value Added of Medium and Advanced Technology Industries in Iran from 1990 to 2021

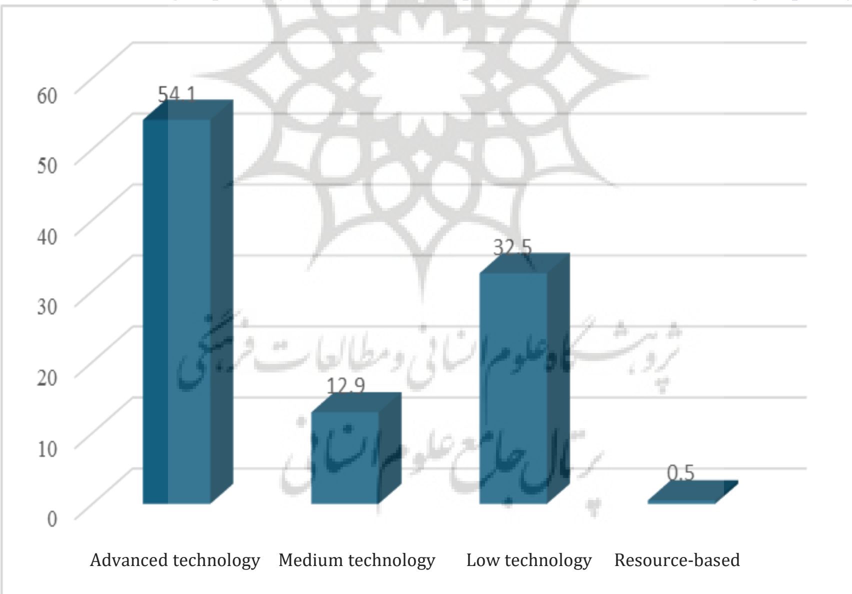


(Source: Calculations based on data from the UNIDO Database: CIP - Competitive Industrial Performance Index)

An examination of Iran's industrial exports reveals that the majority are currently resource-based, with a very small share coming from advanced-technology industries. Although the exports of medium technology industry accounts for a significant share and ranks second (Figure 10), over 54% of Iran's industrial exports are resource-based products, and only about 0.5% are from advanced technology products. Approximately 33% of Iran's industrial exports are from medium-technology products, and around 13% come from low-technology industries.

A suitable strategy for Iran would be to increase the share of exports from advanced industries. Given the significant share of medium-technology industry exports, appropriate investments in these industries could lead to advancements in their technology and quality. Additionally, as indicated by the Complexity Outlook Index in the previous section (Figure 4), the Iranian economy has considerable potential to enhance the complexity of its products, which is essential for the competitiveness of its industries in the medium and long term. By increasing the share of medium-technology industry exports, it is feasible to move towards upgrading these products to advanced technology products and reduce the share of resource-based exports.

Figure 10.
Structure of Iran's Manufacturing Exports (Share of Iran's Exports in Total Manufacturing Exports) in 2021



(Source: UNDP, the Competitive Manufacturing Performance (CIP), 2021)

In summary, an examination of various science and technology indicators in Iran's manufacturing sector showed that the upward trend of these indicators continued until the late 1380s (2000s in the Gregorian calendar). During this period, the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar), with the onset of economic sanctions, the technological advancement trend in the manufacturing sector has halted. Accordingly, the Iranian economy has remained relatively stagnant, even showing backward movement in some indicators.

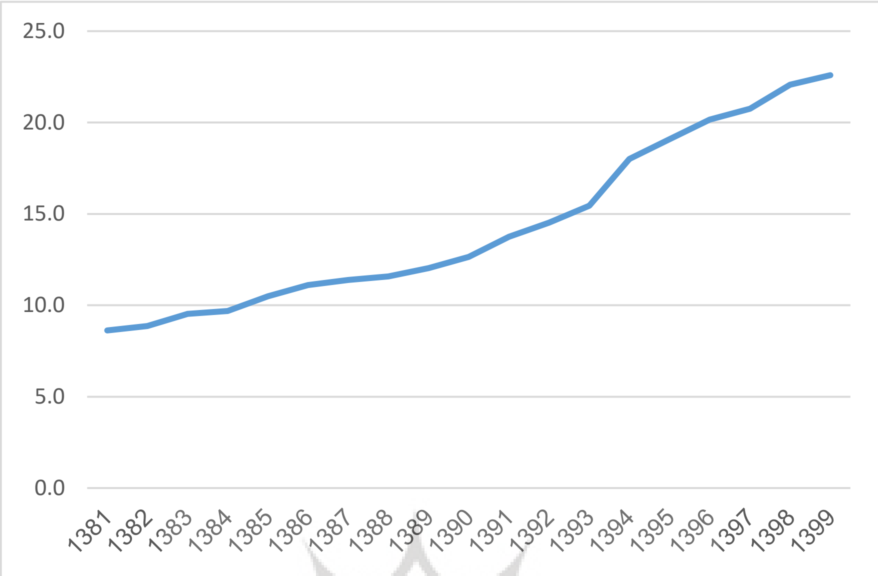
Nevertheless, given the potential of the Iranian economy, appropriate policymaking could partially rectify this trend. Specifically, focusing more on high-tech industries and implementing policies to increase competition, with the aim of enhancing innovation incentives, could improve this situation. It is important to note that if the current trajectory continues, Iran risks losing its position in global markets and, in the medium term, results in a decrease in its economic power.

One of the pathways for technology transfer to the industrial sector is through the recruitment of educated and skilled human resources. According to the literature on economic growth, knowledge enhancement and the accumulation of human capital are the key sources of growth in the industrial sector. Two major indicators—the share of employees in the industrial sector with a bachelor's degree or higher, and the ratio of training expenses to the value added of industrial workshops with ten or more employees—reflect the changes and developments within the industrial sector in terms of science and technology.

The share of employees in the industrial sector with a bachelor's degree or higher indicates the average level of education among the workforce in this sector. An analysis of this trend (Figure 11) shows that the share of employees with a bachelor's degree or higher has increased over time, demonstrating a consistent upward trend. In other words, the structure of employment in the industrial sector is shifting in favor of university education. However, this shift alone is not sufficient for economic growth; it is crucial to consider how employees with higher education are utilized in the industrial sector and what conditions are necessary for their effective integration. Otherwise, the industrial sector may merely absorb changes occurring in the labor market without gaining substantial benefits from the more educated workers.

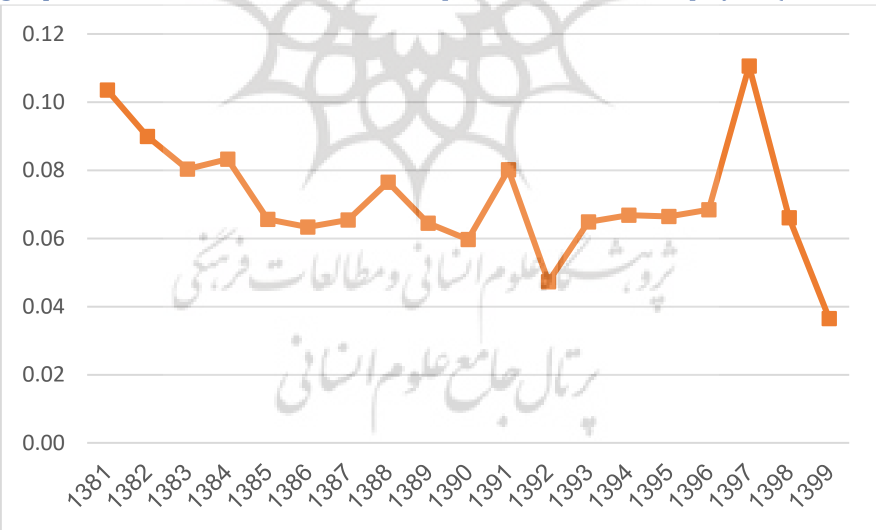
The ratio of training expenses to the value added of industrial workshops with ten or more employees can also serve as a measure of the efforts made by enterprises to empower their human resources (Figure 12). This indicator shows how much businesses invest in enhancing their workforce. Contrary to the smooth upward trend in the share of more educated workers in the industrial sector, the ratio of training expenses to the value added of industrial workshops with ten or more employees is not only negligible (even at its peak, it does not exceed 0.11% of the value added), but also downward. This indicates that the industrial sector is making little effort to enhance human resources through training. Accordingly, this sector, failing to make adequate investments in this area, relies on the knowledge human resources gain through formal education and the experience they accumulate over time.

Figure 11.
Share of Employees with a Bachelor's Degree and Higher among Total Employees in Industrial workshops with Ten or More Employees (Percentage)



(Source: Calculations Based on the Statistics of Industrial Workshops with ten or more Employees from the Statistical Center of Iran)

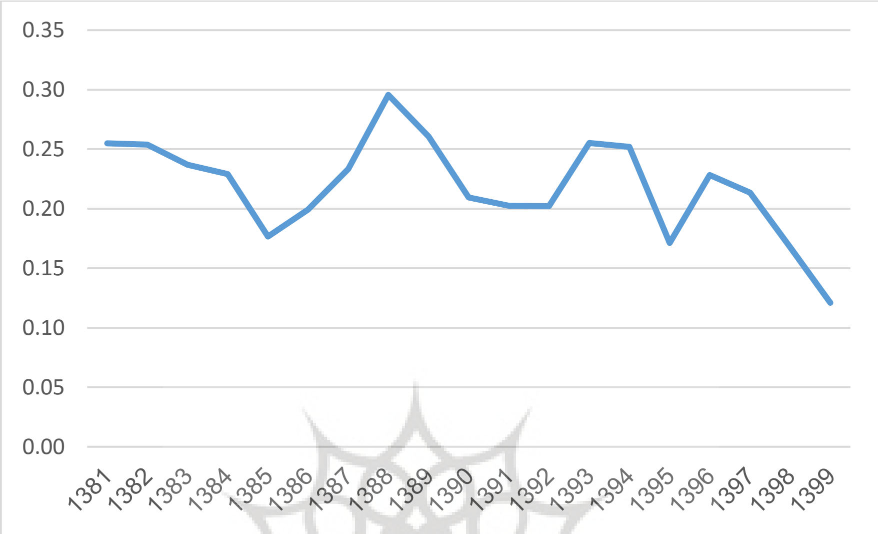
Figure 12.
Ratio of Training Expenses to the Value Added of Workshops with Ten or More Employees (Percentage)



(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

On the other hand, research and development activities are key to enhancing the technological capabilities of enterprises and industries. Indicators show that Iran is not performing well in this area compared to the global average. This issue is examined at the industrial sector level by analyzing the ratio of research and laboratory expenses to the value added of enterprises, as a measure of research and development activity level (Figure 13). Contrary to the smooth upward trend of the share of more educated workers in the industrial sector, the ratio of research and laboratory expenses to the value added of industrial workshops with ten or more employees is not only negligible (even at its peak, it does not exceed 0.3% of the value added, which is significantly lower than the national average of 0.5%), but also downward.

Figure 13.
Ratio of Research and Laboratory Expenses to the Value Added of Workshops with Ten or More Employees (Percentage)

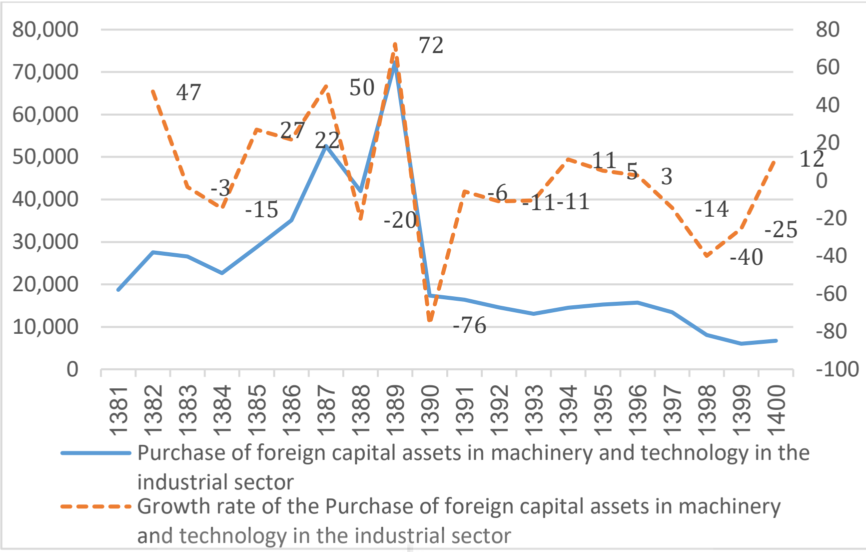


(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

It is important to note that one of the pillars of the Global Innovation Index is knowledge absorption, indicating that one of the ways of absorbing knowledge is importing advanced technologies. Historically, technology transfer through machinery and equipment has always been one of the most important ways of technology transfer and enhancement in the Iranian economy. A significant portion of Iran's imports has consistently consisted of capital goods, indicating Iran's considerable demand for technology. This trend is also evident in the industrial sector. Given the importance of this issue, this section aims to examine the structure of investments in machinery and technology in the industrial sector from various aspects, considering both temporal trends and distribution across different industrial activity categories. Each of these aspects depicts only one part of the industrial sector's structure. Hence, when they are combined, they provide overall comprehensive picture.

Initially, the trend of purchasing or acquiring machinery and technology from abroad at constant prices (right vertical axis) can be examined alongside its growth (left vertical axis) (Figure 14). This indicator effectively shows how much the industrial sector has spent (at constant prices) on purchasing foreign machinery and technology. Notably, since 1390 (2011), the trend of purchasing foreign capital assets in Iran's industrial sector has been declining. Although there was a slight increase in this variable during the 1390s (2010s), the overall reduction in foreign capital purchases in the industrial sector is clearly less than in the previous decade.

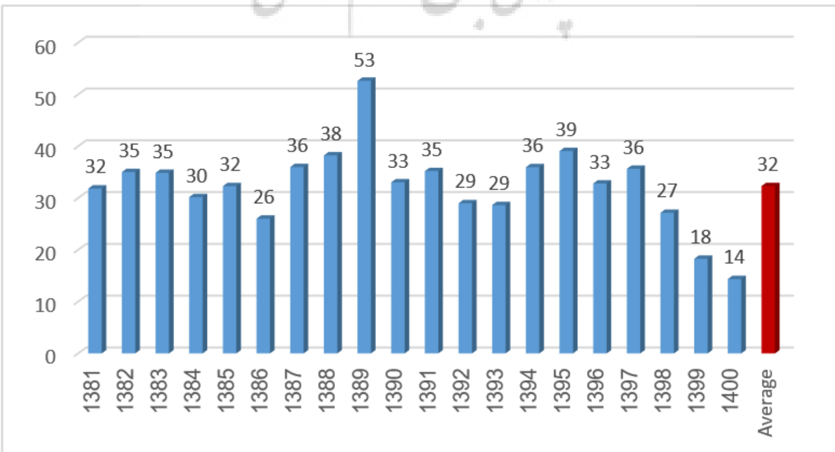
Figure 14.
Purchase or Acquisition of Foreign Capital Assets in Machinery and Technology in the Industrial Sector (Fixed Billion Rials)



(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

The decline in the value of foreign equipment purchases in the 1390s (2010s) can be observed in relation to the total capital assets acquired in the industrial sector. In other words, when the share of foreign capital assets relative to the total capital assets acquired in this sector has decreased, it suggests that the pathway for technology transfer through foreign machinery has weakened. This trend is illustrated in Figure 15. Specifically, from 1381 to 1399 (2002 to 2020), this ratio averaged 33%, indicating a substantial reliance on foreign purchases for supplying capital assets in industrial workshops with ten or more employees. However, in the 1390s, a relative decline can be observed in this ratio, especially in 1398 and 1399 (2019 and 2020).

Figure 15.
Share of Purchases or Acquisitions of Capital Assets in Machinery and Technology from Abroad Relative to Total Capital Assets in the Industrial Sector (Percentage)



(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees From the Statistical Center of Iran)

Discussion and Conclusion

The aim of this article is to examine technological trends in Iran's manufacturing sector over time. The importance of studying these trends lies in the fact that maintaining the competitiveness of the Iranian economy, particularly in the manufacturing sector, requires medium- and long-term investment in knowledge and technology. In recent decades, serious competition in the global economy has made traditional economic advantages, such as cheaper energy, low-cost labor, access to natural resources, economies of scale, and mass production, insufficient for an industry's success. Therefore, additional advantages are necessary to remain competitive in the global market. Under these conditions, neglecting investment in science and technology could weaken cpuntries' manufacturing sector in the long run.

The findings of this article indicate that Iran's human capital is at an average global level, but with right policies, this situation could be improved. Given the significant investments made in public education and the expansion of universities over the past decades, issues such as the return on education, the quality of education, and the educational structure of the country play an important role in shaping the outcome.

An examination of the Iranian economy in terms of science and technology indicators shows that Iran ranks as an average country globally in this respect. However, in terms of research and development expenditure, which reflects investment in science and technology, greater attention and effort are needed to prevent Iran from lagging behind the trends adopted by countries in the Middle East, North Africa, and other successful developing countries.

By analyzing various science and technology indicators within Iran's manufacturing sector, we can argue that these indicators exhibited an upward trend until the late 1380s (2000s in the Gregorian calendar). Overall, the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar), with the onset of economic sanctions, technological advancement in the manufacturing sector has halted, leaving the Iranian economy relatively stagnant and even showing backward movement in some indicators. Nevertheless, given the potential of the Iranian economy, appropriate policymaking could help reverse this trend. Specifically, greater attention to high-tech industries and policies aimed at increasing competition to enhance innovation incentives could improve the situation. It is important to note that if the current state continues, Iran risks losing its position in global markets and, in the medium term, results in a decrease in Iran's economic power.

Considering the overall findings of this research, indicating a decline in the technological activities of Iran's manufacturing sector over the past decade, the following hypothesis is confirmed: economic instability in the manufacturing sector, on the one hand, and macroeconomic developments in the country, on the other hand, have created an unfavorable environment for Iran's industries. This has led entrepreneurs and manufacturing owners to focus more on maintaining existing performance rather than increasing competitive capacity and innovation, thus hindering activities and efforts for gaining a larger share of the global market.

Based on the findings, the following strategies can be proposed to enhance Iran’s industrial sector in terms of science and technology, and consequently, increase its competitiveness in the medium term:

- *Serious attention to competitive policies that increase demand for science and technology*. As shown in the article, the industrial sector had fewer technological activities in the 1390s (2010s). One reason for this decline can be attributed to the tightening of Iran's economy (due to economic sanctions and shifting towards protectionist policies), which has led to reduced competition. Therefore, one of the fundamental strategies could be to increase Iranian industries’ exposure to competition- particularly foreign competition- in a measured and reasonable way.
- *Attention to stabilizing policies in the industrial sector and seriously addressing barriers to production and investment*. As mentioned, Iran’s industrial sector has experienced greater volatility compared to the overall Iranian economy, leading to decreased technological activities. Thus, focusing on stabilizing policies and removing production barriers could reverse this trend. Frequent changes in policies, unfavorable macroeconomic conditions, and policies such as price controls have reduced the productivity of this sector and increased its risks. Addressing these issues could enhance the demand for science and technology in the industrial sector, which is necessary for maintaining competitiveness in the medium term.

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