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Analysis of the Relationship between the Number of Patents in the Field of Reverse Engineering and the Gross Domestic Product of Countries

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ABSTRACT

Objective: Reverse engineering is an effective tool for developing countries to utilize the technologies of advanced nations, enabling them to overcome technological limitations and increase innovation and gross domestic product (GDP). This research aims to analyze the status of China, Japan, South Korea, and Iran in the field of reverse engineering and to explore its relationship with the number of patents and their GDP.

Methods: This applied research was conducted using document analysis and bibliometric techniques. The statistical population of this study consisted of articles in the field of reverse engineering published by China, Japan, South Korea, and Iran in the Scopus citation database, as well as their patents in the WIPO database and their GDP data from the World Bank, covering the period from 2010 to 2019. Data was collected through note-taking, and Pearson's correlation coefficient was used to analyze the data.

Results: The results show that there is no significant relationship between reverse engineering articles and GDP between Iran and selected countries. Although the rising share of the production of articles shows that countries at some point in time and before starting innovation, pay a lot of attention to reverse engineering, after some time they achieve scientific prosperity and seek to create innovation and new patents. There is also no clear relationship between the field of reverse engineering and the number of patents granted. This shows that reverse engineering and the granted patent are not always in the same direction or the opposite. In countries like South Korea and Japan, reverse engineering and patents go in the same direction, but in China, they go in the opposite direction.

Conclusion: This indicates that after passing through the reverse engineering stage, countries utilize the knowledge gained to innovate products and file new patents. Reverse engineering fosters innovation, leading to an increase in patent filings. However, as countries reduce their reliance on reverse engineering, they transition toward more independent innovation. The rise in innovation further boosts patent activity and contributes to the growth of their gross domestic product (GDP). Therefore, it can be concluded that reverse engineering is effective in driving innovation and increasing GDP in developing countries. An increase in GDP, in turn, can help improve the economic conditions of these countries across various sectors.

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Introduction

Reverse engineering is the process of discovering the technological principles of a device, object, or system through the analysis of its structure and functions. The use of reverse engineering to develop technology and grow industries and sciences in developing countries is an accepted strategy (Chikofsky & Cross, 1990). Governments and businesses innovate in various ways, including importing technology in the form of capital goods, trade agreements, producing it through R&D, and learning from suppliers using reverse engineering. Reverse engineering has been a successful strategy for East Asian countries in transferring technology, overcoming technological backwardness, and achieving economic development (Lee et al., 2011). Iran can reduce its technological gap with developed countries in a short time by following their example and gaining a significant share in world trade. Reverse engineering can be used to determine how a product works or to learn the ideas and technologies used for product development (Dehaghi & Guderzi, 2011).

Surveys show that Iran has been oblivious to the importance of technology for years, resulting in it lagging behind developed countries. Due to the long-term processes required to transform research ideas into economic products, the deep scientific gap between developing and developed countries is increasing every day. Therefore, the best way to compensate for this backwardness is to use the successful experiences of others in new developments. Transferring technology and using reverse engineering is a shortcut to achieve the results of other countries' research to solve their own problems (Valizadeh & Akbari, 2019). Reverse engineering is one of the cheaper methods of transferring technology and knowledge that developing countries pay special attention to (Shakarchi, 2011). It is useful and necessary for developing countries that do not have the facilities to produce original and new knowledge and technology (Haji Zain al-Abidini, 2008). It is very effective for compensating the costs of delayed returns on scientific productions and for the realization of emerging industries. It can significantly impact the acquisition of technical knowledge of products in the shortest time and at the least cost (Dehaghi & Guderzi, 2011), leading to faster development and innovation.

For example, China has used reverse engineering to transform from a developing country to one of the largest economies in the world with the highest economic growth rate today (Waziri & Awomolo, 2015). However, Iran has not been as successful in using reverse engineering compared to countries like Japan, South Korea, and China. This is because it has not been successful in creating innovations, such as new inventions, to increase its GDP. Patent licenses are one of the most important indicators that influence the creation of innovation in the economic growth of countries (Schick, 2019).

Therefore, considering the importance of reverse engineering and its benefits for developing countries, including Iran, on one hand, and the significance of patents as a mechanism for technology transfer on the other, it is essential to recognize that technology and innovation are engines of economic growth (Josheski & Koteski 2011). In addition to the importance of gross domestic production (GDP), which is a measure of the economic growth rate of each country (Schick 2019), there is a growing concern about how to investigate the reverse engineering situation using citation and patent databases such as Scopus and WIPO in Iran, China, Japan, and South Korea. There is also growing concern about whether there is a connection between reverse engineering, patents, and GDP. In this regard, the aim of this research is to analyze the scientific metrics of articles, patents and gross domestic product of Iran and the countries of South Korea, Japan and China by answering the following questions:

1. What is the trend and contribution of China, Japan, South Korea and Iran in publishing articles in the field of reverse engineering, patents and GDP from 2010-2019?
2. The relationship between articles in the field of reverse engineering and the amount of GDP (gross domestic product) and the amount of patent licenses granted in China, Japan, South Korea and Iran from 2010-2019?
3. The relationship between GDP and the number of patents granted in China, Japan, South Korea and Iran relative to each other and their population from 2010-2019?

Materials and Methods

This research is of an applied type, which uses documentary and scientometric methods to analyze the number of reverse engineering articles in Iran, South Korea, Japan and China in the Scopus reference database. Patents and their gross domestic product in the WIPO database and the World Bank website have used. The reason for choosing the countries in question to compare with each other is that they are developing and developed, and they are more advanced in publishing articles, patenting, and gross domestic product compared to other countries. In this research, because the patent statistics Countries are available in the WIPO database from 2010 to 2019, so the sample size of patent patents of the countries is based on this time period. selected and Also, to determine the relationship between patents and GDP taken from the World Bank website and to determine the relationship between them and the number of reverse engineering articles in the Scopus citation database from the time period Used 2010-2019 . He also used the Pearson correlation coefficient to determine the relationship between the number of articles published in the field of reverse engineering with GDP and patent licenses of countries.

In addition, to extract the number of articles related to reverse engineering from the advanced search function of the Scopus database Used. This means that to extract articles with reverse engineering keywords from the fields code section of the keyword option And then the option index term, which is the indexed terms of each article by the database, has been used. After selecting the

index term and adding the INDEXTERMS function to the enter query string section, the term reverse engineering has been searched for at this stage, 17,778 articles have been retrieved. To retrieve articles in selected countries (China, Japan, South Korea and Iran) in the Refine results section, select the desired country from the Country/Territory section and press the limit button to extract the articles for the desired country. Finally, the World Bank website was used to extract GDP data and demographic information for the selected countries. Additionally, data from the WIPO database for the period 2010–2019 was extracted by following these steps: after accessing the database site, the "Country Profile" option was selected from the Resources tab. Next, the name of the country was chosen from the country menu, and the "IP Statistical Profile" option was clicked in the Statistics section. This allowed for the extraction of statistics related to patents, trademarks, industrial designs, and patent grants for the selected countries. This means that after accessing the open data section of the global site and searching for the term "GDP," the GDP index (current $) was selected from the Download section, and the output was prepared in an Excel file format. To analyze the information extracted from the WIPO, Scopus, and World Bank databases, SPSS 26 software was used. Since the data on granted patents, gross domestic product (GDP), and the number of articles published in the field of reverse engineering are all numerical and quantitative, measured at the interval level, the Pearson correlation test was employed to determine the relationship between the variables. Additionally, pairwise correlations between the variables were calculated to assess their interrelationships.

Results

Figure 1 shows the trends in articles, patents, and gross domestic product (GDP) in the field of reverse engineering for selected countries from 2010 to 2019. According to Figure 1, the number of articles published by these countries fluctuated between 2010 and 2019, with the highest number of articles published in 2011 (381 titles) and the lowest in 2017 (280 titles). Figure 1 also indicates that the trends for both patents and GDP have been upward from 2010 to 2019. Specifically, the number of patents increased from 561,286 in 2010 to 989,960 in 2019, while GDP rose from 533,717 thousand dollars to 722,057 thousand dollars during the same period.

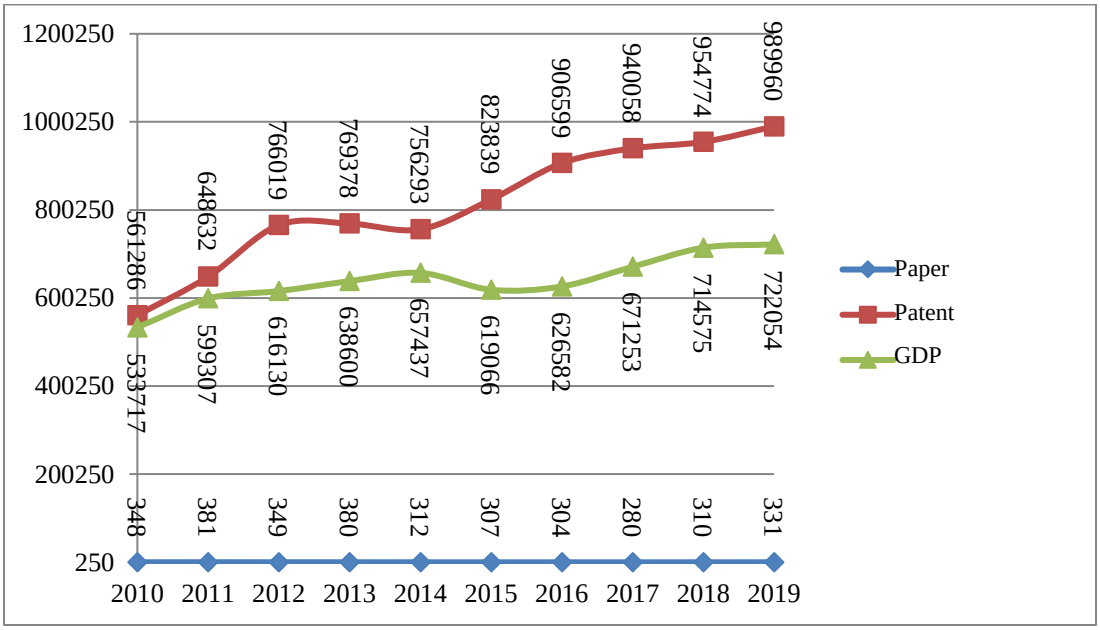

Figure 1. The trend of articles, patents and gross production of countries from 2010-2019

Figure 2 presents the contributions of China, Japan, South Korea, and Iran in publishing articles in the field of reverse engineering, as indexed in Scopus. According to the findings in Figure 2, China has published the most articles, with 2,391 articles (72%), followed by Japan with 369 articles (11.18%), South Korea with 366 articles (11.08%), and Iran with 176 articles (5.33%). China's significant lead in the number of publications highlights its substantial focus on the field of reverse engineering compared to South Korea, Japan, and Iran.

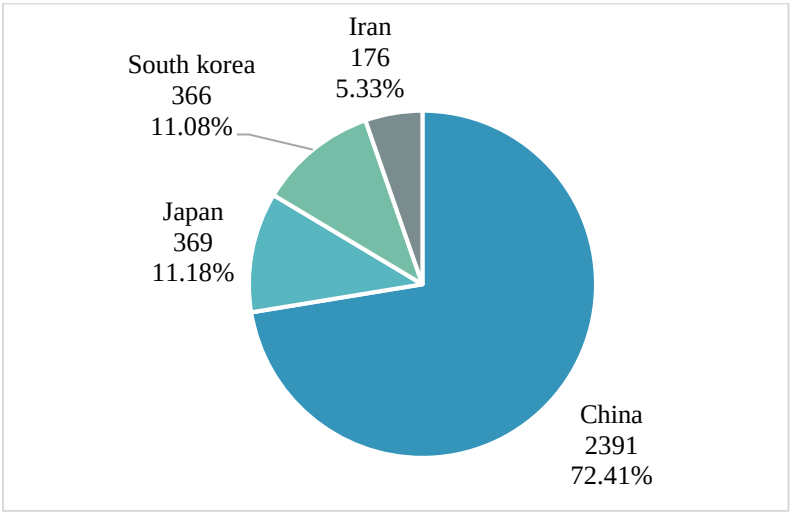

Figure 2. Selected countries' share of published articles from 2010-2019

According to the findings in Figure 3, Japan has registered 3,422,521 granted patents (42.17%), China 3,209,932 (39.55%), South Korea 1,447,640 (17.84%), and Iran 36,745 (0.45%) in the

WIPO database. Figure 4 illustrates the GDP of China, Japan, South Korea, and Iran from 2010 to 2019, as reported on the World Bank website.

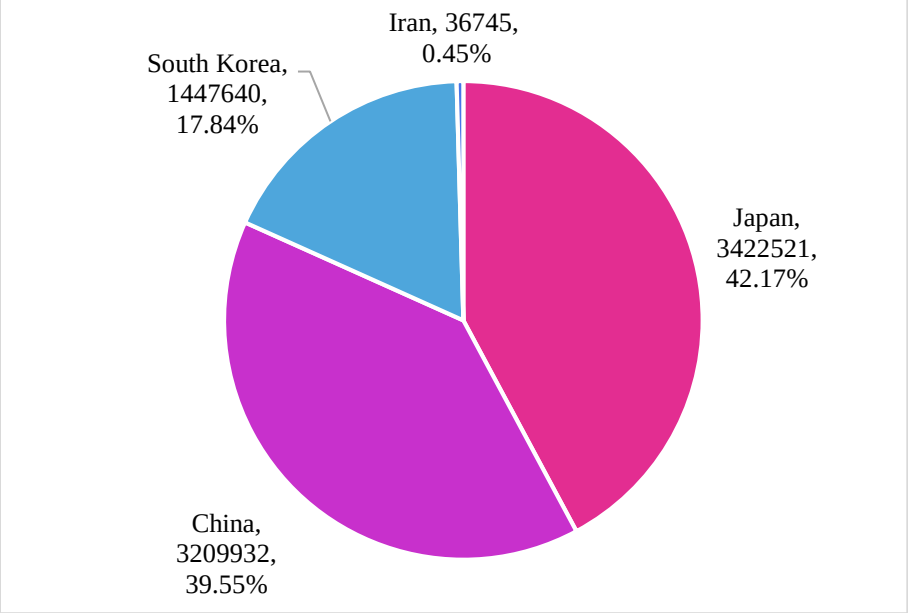

Figure 3. Countries' share of patents granted from 2010-2019

According to the findings of Figure 4, among the selected countries, China has the largest share of GDP with an approximate amount of 105 thousand billion dollars and a share of about 60 percent, and Iran has the lowest share of the GDP of the selected countries with about 2.5 percent.

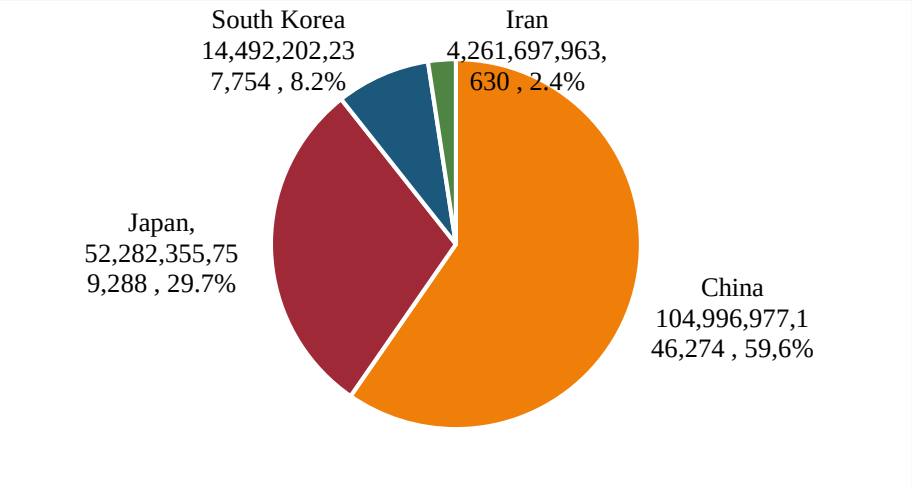

Figure 4. Countries' share of GDP between 2010 and 2019

Table 1 shows the relationship between articles in the field of reverse engineering and the amount of GDP of China, Japan, South Korea and Iran.

Table 1. The results of the relationship between the number of articles in the field of reverse engineering and the amount of GDP from 2010-2019

Country	Significance level	The correlation	Result
Country	Significant level	The correlation	Type of relationship
China	0.032	-0.676	Average inverse relationship
Japan	0.432	0.281	No meaningful relationship
South Korea	0.029	0.685	Strong direct relationship
Iran	0.529	-0.226	No meaningful relationship

Based on the findings in Table 1, the relationship between GDP and reverse engineering in China from 2010 to 2019 is moderately inverse, with a significance level of 0.032 and a correlation coefficient of -0.676. This indicates that while the number of published articles in the field of reverse engineering has decreased, China's GDP has increased. In contrast, the relationship between GDP and reverse engineering articles in Japan, with a significance level of 0.432 and a correlation coefficient of 0.281, is not statistically significant. However, in South Korea, there is a strong direct relationship between GDP and reverse engineering articles from 2010 to 2019, with a significance level of 0.029 and a correlation coefficient of 0.685. This suggests that as the number of published articles in the field of reverse engineering increased, South Korea's GDP also rose. In Iran, no significant relationship exists between GDP and reverse engineering during the same period, with a significance level of 0.529 and a correlation coefficient of -0.226. Overall, the findings demonstrate that the relationship between published articles in reverse engineering and GDP varies significantly across countries.

Table 2 indicates the relationship between articles published in the field of reverse engineering and the number of patents granted in China, Japan, South Korea, and Iran.

Table 2. The results of the relationship between articles in the field of reverse engineering and the number of patents granted from 2010-2019

Country	Significance level	The correlation	Result
Country	Significant level	The correlation	Type of relationship
China	0.008	-0.78	Strong inverse relationship
Japan	0.507	0.123	No meaningful relationship
South Korea	0.276	0.375	No meaningful relationship
Iran	0.691	-0.144	No meaningful relationship

Based on the findings in Table 2, there is a strong inverse relationship between granted patents and reverse engineering articles in China from 2010 to 2019, with a significance level of 0.008 and a correlation coefficient of -0.78. This indicates that during these years, China established an

inverse relationship between reverse engineering and granted patents, suggesting a strategic shift toward innovation and the development of new inventions, positioning the country as a technological leader. Additionally, the findings reveal no significant relationship between granted patents and reverse engineering articles in Japan, with a significance level of 0.507 and a correlation coefficient of 0.123, or in South Korea, with a significance level of 0.286 and a correlation coefficient of 0.375. However, in Iran, there is a weak inverse relationship between granted patents and reverse engineering articles from 2010 to 2019, with a significance level of 0.691 and a correlation coefficient of -0.144.

Table 3 illustrates the relationship between gross domestic product (GDP) and the number of patents granted in China, Japan, South Korea, and Iran.

Table 3. The results of the relationship between country significance level the correlation result

Country	Significance level	The correlation	Result
Country	Significant level	The correlation	Type of relationship
China	0	0.944	Strong direct relationship
Japan	0.133	0.509	Direct average relationship
South Korea	0.002	0.845	Strong direct relationship
Iran	0.005	0.807	Strong direct relationship

Based on the findings in Table 3, there is a very strong relationship between the number of patents granted and China's GDP, with a significance level of 0 and a correlation coefficient of 0.94. Similarly, a moderate relationship exists between the number of patents granted and Japan's GDP, with a significance level of 0.133 and a correlation coefficient of 0.509. In South Korea, there is a very strong relationship between the number of patents granted and GDP, with a significance level of 0.002 and a correlation coefficient of 0.845. Additionally, a very strong relationship is observed between the number of patents granted and Iran's GDP, with a significance level of 0.005 and a correlation coefficient of 0.807. This indicates that as one variable increases or decreases, the other variable moves in the same direction. Overall, among the studied variables, there is a direct relationship between GDP and the number of patents granted in the selected countries. In other words, GDP and the number of patents granted move in tandem, increasing or decreasing together. Among the selected countries, the strongest relationship between patents granted and GDP is observed in China, highlighting the strong connection between innovation and economic growth in the country. Conversely, the weakest relationship is found in Japan, suggesting the influence of other factors on the Japanese economy.

Table 4 examines the relationship between gross domestic product (GDP), the number of patents granted, and population size in China, Japan, South Korea, and Iran.

Table 4. Comparison of gross domestic product and granted patents with the ten-year population average of the countries

Country	Ten-year population average	GDP	GDP per capita	No. of patents granted	Population per patent granted
Japan	127,196,833	52,282,355,759,288	411,035.04	3,422,521	37.16
China	1,368,090,500	104,996,977,146,274	76,747.10	3,209,932	426.2
South Korea	50,777,654	14,492,202,237,754	285,405.12	1,447,640	35.07
Iran	78,132,939	4,261,697,963,630	54,544.19	36745	2,126.3

Table 4 shows that during the years 2010 to 2019, South Korea has 35 people for every patent granted, while Japan and China have 426 people per patent, and Iran has one patent for every 2,126 people. This indicates that Iran is significantly behind the other countries in this regard. Additionally, the findings indicate that in terms of GDP per capita, Japan has the highest at 411, 035, followed by South Korea with 285,000, China with 76,747, and Iran with 54,544. Iran has the lowest GDP per capita among these countries.

Discussion

The use of reverse engineering, the application of inventions, and the adoption of advanced technologies from developed countries play a significant role in creating knowledge, fostering innovation, and increasing GDP. This research aims to compare the status of reverse engineering articles, patents, and GDP in China, Japan, South Korea, and Iran from 2010 to 2019. The results indicate that while the GDP and number of patents in these countries have shown an upward trend, the number of reverse engineering articles has decreased. China, with over 72 percent of articles published on reverse engineering, stands out significantly compared to Japan, South Korea, and Iran. This may be attributed to China's ability to absorb new technologies from advanced countries, improve learning processes, enhance economic growth, develop new innovations, and implement effective management, foresight, and policy-making. These findings are consistent with the research of Shekarchizadeh (2011), Aqlai, Karimi, and Jafaranjad (2013), Waziri and Awomolo (2015), and Zhang & Zhou (2016).

A strong negative relationship between reverse engineering articles and China’s GDP indicates that China has moved beyond this stage, transitioning from reverse engineering to product innovation. Consequently, Japan, South Korea, and Iran can follow China’s example to facilitate and accelerate the process of leveraging reverse engineering to create new innovations and increase their GDP. In Japan, the relationship between reverse engineering and GDP has diminished, while South Korea continues to use reverse engineering to boost GDP, demonstrating a direct and strong

correlation between the number of reverse engineering articles and GDP. However, the low number of articles published by Iran, compared to China, Japan, and South Korea, highlights Iran's lack of emphasis on the importance of reverse engineering in increasing patents and GDP. This may be attributed to factors such as neglect of domestic production, oil embargoes, economic instability, underutilization of skilled professionals in economic management and policymaking, insufficient infrastructure, lack of support for researchers and scientific activists, and inadequate economic and scientific diplomacy. These issues have exacerbated Iran's economic challenges and contributed to the decline in its GDP.

Additionally, the results showed that there is no specific relationship between the number of reverse engineering articles and patents in countries other than China. However, a relationship exists between the number of patents granted and GDP. These results indicate that the economy and innovation have a mutual and bidirectional relationship, where the rise and fall of one strongly influences the other. According to the research by Azad, Nokarizi, and Ghasemi (2013); Lashgari, Asadpour, Samimi, and Asadpour (2018); Shakri and Kayseri (2019); Schick (2019); Khalili, Lau, and Cheong (2016); Sha (2011); and Josheski & Koteski (2011), countries that invest in innovation and technology, whether through reverse engineering or not, see positive results in their economy, leading to the growth of their GDP. The positive relationship between the number of patents and GDP reflects the scale and level of economic and industrial development in countries. Furthermore, a comparison of GDP per capita shows that Iran is not far behind China; however, Iran has not effectively utilized its resources to drive GDP growth, whereas China has achieved significant growth despite its limited resources.

Other results showed that China and Japan accounted for more than 80 percent of patents granted from 2010 to 2019, with Japan having more patents granted than China, South Korea, and Iran, despite publishing relatively few articles in the field of reverse engineering. This highlights Japan's focus on developing innovative products across various fields. The difference in patents granted becomes even more pronounced when adjusted for the population of each country.

Conclusion

The results show that reverse engineering is a common method in both developing and developed countries to achieve technological advancement. Iran can achieve significant success in this field by following the example of successful Asian countries such as China, Japan, and South Korea. The strong inverse relationship between reverse engineering publications and the number of patents granted in China, as well as the strong correlation between patents granted in Japan and its GDP, indicate the high capability of China and Japan to foster innovation. These countries have used reverse engineering as a tool to absorb technology from advanced nations and enhance learning from 2010 to 2019. Therefore, it can be argued that these countries have adopted reverse

engineering with a different attitude and approach compared to others, leveraging the knowledge gained to innovate products and register new patents. This demonstrates a direct relationship between patents and GDP. Consequently, South Korea and, particularly, Iran can utilize reverse engineering to increase their innovations and GDP by following the strategies of China and Japan. Reverse engineering fosters innovation and patenting, and increased focus on innovation leads to GDP growth, which in turn drives further innovation and patenting in these countries (Figure 5).

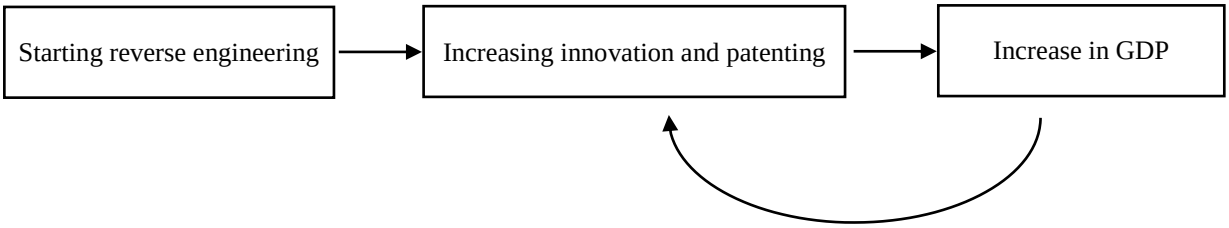

Figure 5. The relationship between reverse engineering, patents and GDP

In general, it can be argued that countries should enhance their innovation and invention capabilities to advance their scientific processes in the field of reverse engineering and increase their GDP. Reverse engineering should be utilized as a tool to foster further innovation. To achieve this, it is recommended that countries support experts and scientists in this field to address and overcome the challenges related to reverse engineering, innovation, and GDP growth. This includes analyzing the root causes of existing obstacles, implementing effective policies and strategic planning, entrusting the management of these initiatives to specialists, and providing the necessary technical infrastructure to support innovation development. Additionally, it is advisable for developing countries, such as Iran, to focus on reverse engineering products that are primarily imported from abroad. By producing these goods domestically, they can meet local demand, create employment opportunities, and stimulate economic growth.

Additionally, by focusing on domestic production and its localization, and by reducing economic dependence on oil through the use of reverse engineering, Iran can achieve economic prosperity and mitigate its vulnerabilities at both national and international levels. Furthermore, since patents granted and GDP in the studied countries exhibit a strong and direct correlation, Iran can also support inventions to drive its economic growth. Instead of allowing the economy to be constrained by sanctions, continuous investment in the field of inventions can transform Iran into an economic powerhouse within a few years, significantly increasing its GDP.

Author Contributions

Conceptualization, F.G. and H.N.; methodology, F.G. and H.N.; software, F.G. and H.N..; validation, F.G. and H.N.; formal analysis, F.G. and H.N.; investigation, F. G.; resources, F. G.; data curation, F.G.; writing—original draft preparation, F.G. and H.N.; writing—review and editing, F.G. and H.N.; visualization, F. G.; supervision, H. N; project administration, H.N. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data can be provided upon request.

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Ethical considerations

The authors avoided data fabrication and falsification.

Conflict of interest

The authors declare no conflicts of interest.

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