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Relationship Analysis of Food Security with Patents and Gross Domestic Products

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Abstract

Purpose: Food security is a critical global challenge that is influenced by research and innovation in the field. Therefore, the objective of this study is to analyze the scientific output of developing countries in food security and examine its relationship with patents and Gross Domestic Product (GDP).

Methodology: This applied research utilized the Scientometric approach. A total of 8,416 papers published between 1992-2023 in the field of food security by developing countries were included in the study using citation databases from Clarivate Analytics. Additionally, patent registrations from the WIPO database and GDP data from the World Bank were analyzed. Information was collected through note-taking, and the data was analyzed using Pearson's correlation coefficient.

Findings: The findings reveal an upward trend in the publication and citation of scientific outputs related to food security in developing countries. China has higher numbers of papers, patents, GDP, and food production index compared to Iran, Japan, and South Korea. There is also a positive correlation observed between population and the number of papers, gross production and the number of papers, food production and the number of published papers, as well as the number of patents and papers citing scientific outputs of countries.

Conclusion: These results highlight the significant relationship between increasing scientific output, GDP, the number of patents, and food security. Greater emphasis on food security contributes to enhanced scientific output, GDP, and innovation. Similarly, increasing scientific output, GDP, and innovation positively impact food security in countries.

Value: This study emphasizes the importance of scientific outputs in driving technological advancements, innovations, and ultimately, ensuring food security in developing countries.

Keywords: Agricultural Biotechnology, Food Security, Biotechnology Development Policies, Gross Domestic Product, Patents**.**

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Extended Abstract

Introduction: Today, the popularity and value of organic food are increasing steadily. The growing demand is mainly driven by consumer concerns about the negative consequences of conventional agriculture on human health and the environment. Particularly in developed countries, consumers perceive organic food as being safer and healthier than non-organic options

Purpose: Food security is one of the most critical challenges in today's world, which is affected by the amount of research and innovation in this field. Therefore, the purpose of this research is to analyze the status of scientific outputs of developing countries in food security and to examine its relationship with the number of patents and their Gross domestic product (GDP).

Methodology: This applied research adopts a scientometric approach. A total of 8,416 papers published between 1992-2023 were included from Clarivate Analytics' citation databases. The study also examines patent registrations in the WIPO database and the GDP of the countries involved. Information was collected through note-taking, and data analysis utilized Pearson's correlation coefficient.

Findings: The findings reveal an increasing trend in publication and citation of scientific outputs related to food security in developing countries. China demonstrates higher numbers of papers, patents, GDP, and food production index compared to Iran, Japan, and South Korea.

Table 1. Correlation between papers counts and the gross production of countries

Country	GDP	Number of papers	Correlation
China	17.73 trillion	6522	0.573
Japan	4.94 trillion	872	0.645
Iran	231.55 billion	572	-0.677
South Korea	1.8 trillion	450	0.793
Total	24.7	8416	0.990

A positive and strong correlation exists between papers counts and countries' GDP, suggesting a mutually influential relationship.

Table 2. Correlation of papers counts with food production of countries

Country	Number of papers	Food production	Correlation
China	6522	103.0	-0.379
Japan	872	99.2	0.892
Iran	572	99.4	0.998
South Korea	450	98.4	0.97
Total	8416	400	0.983

Increasing scientific output shows a positive and strong correlation with the food production index, indicating its impact on food security.

Table 3. Correlation of papers counts with countries' patents

Country	Number of patents	Number of papers	Correlation
China	12224084	6522	0.689
Japan	9671777	872	0.876
Iran	204092	572	0.217
South Korea	3492042	450	0/698
Total	25591995	8416	0/888

There is a positive and strong correlation between the number of patents and paper publications, implying a two-way relationship.

Table 4. Correlation of papers counts with country citations

Country	Number of citations	Number of papers	Correlation
China	103408	6522	0/789
Japan	21615	872	0/819
Iran	6572	572	0/273
South Korea	10674	450	0/987
Total	142269	8416	0/653

Table 4 shows a positive correlation with the number of papers, signifying the significance of food security in developing countries.

Conclusion: The results suggest a significant correlation and mutual influence between the publication of scientific outputs, GDP, the number of patents in countries, and food security. In particular, food security plays a crucial role in promoting scientific output, GDP growth, and fostering innovation. Likewise, an increase in scientific output, GDP, and innovation positively impact food security within countries. The analysis reveals that Iran, China, Japan, and South Korea have achieved commendable levels of food security based on their scientific outputs and patents. This success can be attributed to efforts such as enhancing self-sufficiency in essential product production, bolstering economic growth and job creation in the agricultural sector, supporting agricultural producers and production, promoting productivity and water efficiency, strategic planning, maintaining production capacity, ensuring self-sufficiency in basic products, protecting essential resources, and improving resource productivity. However, recent years have also highlighted certain challenges faced by Iran in achieving food safety. These challenges include neglecting the utilization of scientific outputs and patents, inadequate scientific planning and policy development, failure to prioritize research needs, limited freedom of expression in scientific societies, insufficient application of expertise, neglecting applied research in this field, brain drain, support for elites by foreign countries, lacking research infrastructure, limited cooperation between professionals and responsible organizations, rising food prices, improper food consumption habits, insufficient investment, flawed policy-making, political decisions impacting scientific works and patent registration, and limitations due to international sanctions. Considering the positive association between scientific outputs, patents, GDP, and the development of science, technology, and innovation, as well as their critical role in ensuring food security, it becomes evident that supporting applied research, fostering innovation, preventing the emigration of intellectual elites, leveraging scientific research findings to address food security concerns, implementing precise and principled policies, investing in food security initiatives, promoting scientific cooperation among nations, and considering factors like available resources, pricing policies, resource protection and optimal use, sustainability, household financial capacity, consumer cultures, and demographic indicators are crucial elements in ensuring the food security of nations.

Value: This study emphasizes the importance of scientific outputs in driving technological advancements, innovations, and ultimately, ensuring food security in developing countries.

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Methodology: This applied research utilized the Scientometric approach. A total of 8,416 papers published between 1992-2023 in the field of food security by developing countries were included in the study using citation databases from Clarivate Analytics. Additionally, patent registrations from the WIPO database and GDP data from the World Bank were analyzed. Information was collected through note-taking, and the data was analyzed using Pearson's correlation coefficient.

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Value: This study emphasizes the importance of scientific outputs in driving technological advancements, innovations, and ultimately, ensuring food security in developing countries.

Keywords: Agricultural Biotechnology, Food Security, Biotechnology Development Policies, Gross Domestic Product, Patents.

1. Introduction

Today, the popularity and value of organic food are increasing steadily. The growing demand is mainly driven by consumer concerns about the negative consequences of conventional agriculture on human health and the environment. Particularly in developed countries, consumers perceive organic food as being safer and healthier than non-organic options (Funk and Kennedy, 2016). Consumers in wealthier nations also believe that organic agriculture is better for the environment, climate protection, and animal welfare (Seufert et al., 2017).

In Europe, organic agriculture has a positive public image and is often regarded as a model for sustainable farming. Food security is an essential criterion for organic and sustainable agriculture, ensuring access to sufficient food for a healthy and active life for all members of society. Achieving food security requires attention to various components on national, local, and international levels. Due to its importance, international organizations and institutions are giving special attention to addressing this issue. Currently, providing food security is one of the biggest challenges globally, complicated by factors such as environmental issues, population growth, demand growth, economic and political conditions, cultural influences, and consumption patterns.

Food security is incorporated into macro policies in Iran, most notably through the "National Biotechnology Document of the Islamic Republic of Iran" approved in 2015. The document outlines the goal of utilizing biotechnology to improve agricultural products, achieve relative self-sufficiency, and ensure food security in the country. The policy also emphasizes resolving the national crisis related to food security, health, and the environment. Short-term goals include applying biotechnology to produce 10% of food, health, industrial, mineral, and energy products, while long-term goals aim to reach 20% by the end of the fifth development plan. It is clear that food security holds a special place in the country's macro policies, with various dimensions taken into account.

Despite the emphasis on food security in Iran, recent years have seen a worrying decline in efforts to ensure it. This trend can be attributed to the lack of comprehensive policies on the matter. Achieving food security and effectively monitoring it requires cooperation among organizations and institutions responsible for food production, importation, education, promotion, information, and macroeconomic policies (Qaraizadeh, 2016).

Therefore, macro-policy should focus on fostering innovation, generating new patents, promoting food security, and increasing GDP, as these factors contribute to better food security in different societies. Increasing GDP positively impacts a country's scientific development (Hassanzadeh, 2020), making patent licenses critical indicators that influence scientific development, economic growth, and improved food security worldwide.

In developing countries, creating innovations in the field of food security plays a vital role in enhancing overall food security. Gross domestic product (GDP) serves as a measure of a country's economic growth rate (Schick, 2019) and significantly influences food security outcomes. Studies have demonstrated that countries with higher GDP face fewer challenges in providing food security compared to those with lower GDP. Examining the relationship between food security, the number of patents, scientific research output, and GDP can play a crucial role in improving

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food security within communities. Therefore, this study aims to analyze the relationship between scientific outputs related to food security in the Clarivate databases and assess the number of patents in the Global Brand Database (WIPO) to answer several questions regarding developing countries' contributions to publications, patents, and GDP from 2010-2021, as well as the interrelationship between papers on food security and GDP/patent numbers during the same period. Additionally, the analysis will explore the correlation between GDP, patent numbers, and population figures from 2010-2021.

2. Research Background

Food security is a crucial aspect of sustainable national security, and selecting an appropriate strategy for achieving it is of utmost importance. A study conducted by Salimizadeh (2014) on Iran's economy and self-sufficiency in essential items highlighted the significant factors influencing food security in the country, including the ratio of urban to rural population, grain cultivation area, and irrigation coefficient in agricultural lands. Strengthening the farming sector plays a vital role in ensuring food security in Iran, as it contributes to employment opportunities and economic development. Fostering scientific growth and development in various fields is also necessary to address the needs of the agricultural sector.

Investigating the relationship between scientific productivity indicators and development markers in Asia, Allahiari et al. (2017) discovered a strong correlation between the variables measuring societal development levels and scientific variables. Additionally, the number of scientific outputs showed a significant correlation with three key indicators: human development, gross national product, and gender inequality. Notably, there was a stronger correlation between the index of human development and gender inequality.

Bagherzadeh Azar (2017) examined the state of food security in Iran and its relation to economic variables. The study found that GDP, economic openness, and government investment in the agricultural sector significantly positively impact food security. Conversely, urbanization, population, and food price index negatively affect food security. Furthermore, Qaraizadeh's (2016) analysis of the future of food security in Iran forecasted that optimal conditions can be achieved through proper planning and creating favorable circumstances related to drivers and critical factors affecting food security. The development of the agricultural sector and international trade were identified as major drivers in achieving countries' food security.

Heydari Chaianeh et al. (2019) explored the impact of agricultural development on various aspects of food security in developing nations. They observed that enhancing the farm sector, particularly by increasing the added value of agricultural industry, improves food access, leading to enhanced food security and GDP. Increasing income positively affects all three dimensions of food security, while rising prices negatively impact food security by reducing accessibility and purchasing power. Urbanization has mixed effects on food security but generally leads to a decline in this area. Additionally, Sakhi et al. (2021) studied the relationship between international trade and food security in middle-to-high-income countries. They found that food security initially decreases with trade

development before starting to improve once trade liberalization surpasses a certain threshold.

The growth of scientific outputs and GDP significantly contribute to ensuring food security. Vinkler's (2008) examination of the correlation between the structure of scientific research, scientometrics indicators, and GDP in EU and non-EU countries revealed variations in the number of publications and citations among the countries analyzed, with GDP showing a direct and substantial connection with scientific indicators. Similarly, Świetlik (2018), through an analysis of economic growth levels and food security in selected countries from 2012-2015, discovered a positive association between higher GDP levels and improved food security. High-performing countries in terms of food security were predominantly those experiencing rapid per capita GDP growth. For poorer nations, economic growth and real income growth are vital requirements for enhancing global food security.

Food security also impacts the economic growth, life expectancy, employment, and poverty reduction in developing countries (Manap and Ismail, 2019). The COVID-19 pandemic has further highlighted the influence of crises, such as infectious diseases, on national food security. Beckman et al. (2021) examined the impact of COVID-19 on GDP, food prices, and food security. Their findings indicated a significant decrease in global GDP and grain prices due to COVID-19-related quarantines. Consequently, the number of people facing food insecurity increased compared to the previous year, with an additional 211 million individuals (27.8%) affected.

In light of these challenges, promoting organic agriculture becomes crucial in reducing food insecurity. Dash et al. (2023) investigated the dimensions of food security and sustainability in organic agriculture, highlighting India's contribution to research in this field. The authors emphasized the effectiveness of scientometric studies in enhancing policy-making processes, understanding the growth trajectory of organic agriculture research, as well as facilitating collaboration within universities and research institutions. Overall, a review of research backgrounds underscores various influential factors in ensuring food security at the national level, including population dynamics, urbanization, employment, agricultural growth and development, scientific outputs and citations, food prices, infectious diseases, human development, economic growth, GDP, proper planning, and the creation of favorable conditions. Policymakers in this field must focus on addressing existing obstacles and challenges.

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3. Methodology

This research utilized a scientometrics approach to analyze scientific papers on food security in Iran, South Korea, Japan, and China. The data used for the analysis included citation information from Clarivate (data extraction time 10/16/2022), patent data from the WIPO database, and GDP data from the World Bank website.

The World Bank website was used to extract data on the food production index, while the WIPO database provided information on patent registrations. These countries were chosen because they represent a range of development levels, with some being developing, developed, and advanced nations. Additionally, these countries were selected due to their high publication rates, patent registrations, and higher GDP compared to other Asian countries.

Table 1. Research variables and their place of extraction

	Variables	Extract from
1.	Gross domestic product (GDP) data	The World Bank Organization (https://www.worldbank.org/)
2.	Patent data	World Intellectual Property Organization (https://www.wipo.int/)
3.	Scientific outputs (papers)	Web of Science platform (https://clarivate.com/)
4.	food production index	The World Bank Organization (https://data.worldbank.org/indicator/AG.PRD.FOOD.XD?view=chart)

The study focused on patent registration statistics from 2010 to 2021, as this period had available data in the WIPO database. The sample size for patent registrations was determined based on this timeframe. The relationship between patents and GDP was assessed using data from the World Bank website. The number of food security papers was analyzed using the Clarivate Analytics citation database, specifically considering the period from 2010 to 2021.

The food production index used in this research refers to the price and volume of edible food products that provide nutritional value, excluding coffee and tea. Coffee and tea were excluded from consideration due to their lack of significant nutritional content. The relationships between papers counts published in the field of food security and the GDP and patent registrations of countries were evaluated using Pearson's correlation coefficient.

4. Findings

According to the findings, China has the highest number of papers (6522 papers, 78%) compared to Japan (872 article titles), Iran (572 papers), and South Korea (450 papers) in the Clarivate Analytics database (Figure 1). Furthermore, the findings show a significant difference in the publication rate of scientific papers in China compared to other countries. This disparity may be one of the main reasons for the higher population of researchers in China.

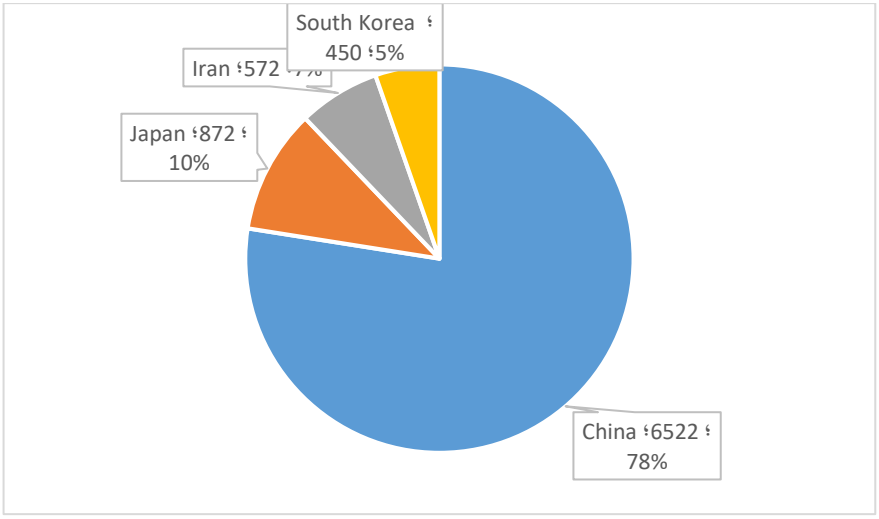

Figure 1. Number of papers published by countries

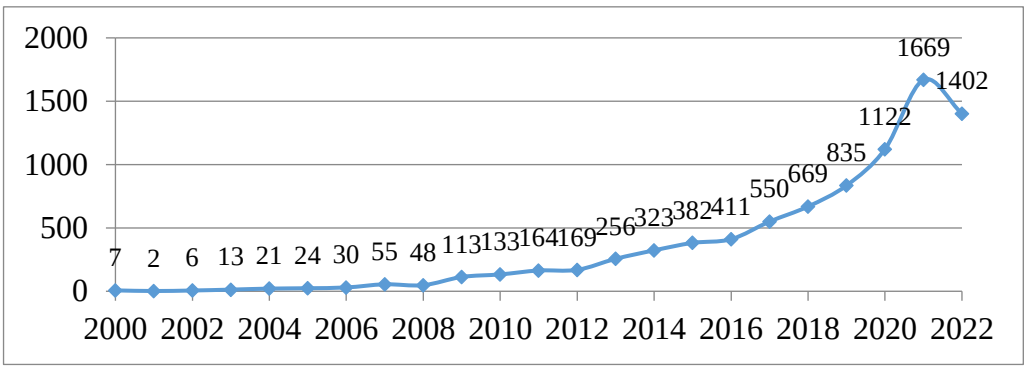

Figure 2. The publication process of countries' papers

The publication trend of the countries' papers has been consistently increasing from 2000 to 2022, with the highest number of papers published in 2021 being 1669 (Figure 2). It should be noted that there were some publications in 1992, 1998, 1999, and 2023, which were not included in figure 1, consisting of one article in 1992 and three articles in 1998. Additionally, four papers were published in both 1999 and 2023.

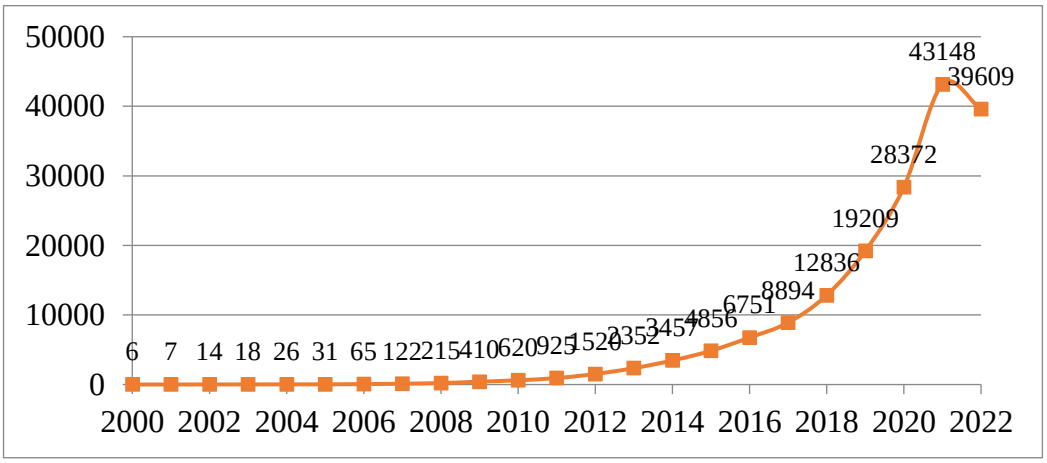

Figure 3. Citation process of scientific outputs

The citation trend of the countries' papers also shows an upward trajectory from 2000 to 2022. Since 2017, there has been a significant jump in the citation trend, which has continued to grow at a high rate since 2019 (Figure 3). This indicates the increasing importance of food security in developing countries. The number of citations to papers has increased from 12,836 citations in 2019 to 43,148 citations in 2022.

Population, gross product, patents, and food production of countries are important factors to consider. In this section, the following components will be explained and compared:

- Population statistics, gross production, patents, papers, and food production of countries
- Correlation between papers counts and the population of countries
- Correlation between papers counts and the gross production of countries
- Correlation between papers counts and the food output of countries
- Correlation between papers counts and country citations

Table 2. Population statistics, gross production, patents, papers, and food production of countries

Country	Population	GDP	Patents	papers	Food production
China	1410000000	17.73 trillion	12224084	6522	103
Japan	125681593	4.94 trillion	9671777	872	99.2
Iran	85028760	231.55 billion	204092	572	99.4
South Korea	51844876	1.8 trillion	3492042	450	98.4
Total	1672455229	256.02	25591995	8416	*

China has a GDP of 17.73 trillion dollars, with 12,224,084 patents and a population of 1,410,000,000. Additionally, they have published 6,522 papers. It is worth noting that China has a better food production status (103.0) compared to other countries (Table 2). Japan, with a GDP of 4.94 trillion dollars, has 9,671,777 patents and a population of 125,681,593 people. They have published 872 papers, which are at a lower level in terms of food production index compared to other countries. Moreover, Iran has a lower GDP than other countries, while South Korea's food production index is also lower.

Table 3. Correlation of papers counts with the population of countries

Country	Population	Number of patents	Correlation
China	1410000000	6522	0.483
Japan	125681593	872	0.678
Iran	85028760	572	0.762
South Korea	51844876	450	0.845
Total	1672455229	8416	0.963

The correlation coefficient between a country's population and its scientific outputs was found to be 0.964 (Table 3). This strong positive correlation suggests

a strong relationship between population size and the number of scientific papers published.

Table 4. Correlation between papers counts and the gross production of countries

Country	GDP	Number of papers	Correlation
China	17.73 trillion	6522	0.573
Japan	4.94 trillion	872	0.645
Iran	231.55 billion	572	-0.677
South Korea	1.8 trillion	450	0.793
Total	24.7	8416	0.990

Similarly, the correlation between a country's GDP and papers counts published was found to be 0.99 (Table 4), indicating a strong positive correlation. In other words, an increase in GDP is associated with an increase in the number of scientific papers, and vice versa.

Table 5. Correlation of papers counts with food production of countries

Country	Number of papers	Food production	Correlation
China	6522	103.0	-0.379
Japan	872	99.2	0.892
Iran	572	99.4	0.998
South Korea	450	98.4	0.97
Total	8416	400	0.983

Furthermore, a strong positive correlation of 0.983 (Table 5) was found between papers counts published by countries and the food production index. This implies that increasing scientific outputs positively impact food security.

Table 6. Correlation of papers counts with countries' patents

Country	Number of patents	Number of papers	Correlation
China	12224084	6522	0.689
Japan	9671777	872	0.876
Iran	204092	572	0.217
South Korea	3492042	450	0.698
Total	25591995	8416	0.888

The correlation between the number of patents and the publication of papers in countries was determined to be 0.888 (Table 6). This indicates a positive and strong correlation between the two. Therefore, there is a reciprocal relationship between papers counts and patents.

Table 7. Correlation of papers counts with country citations

Country	Number of citations	Number of papers	Correlation
China	103408	6522	0/789
Japan	21615	872	0/819
Iran	6572	572	0/273
South Korea	10674	450	0/987
Total	142269	8416	0/653

Additionally, a positive correlation of 0.653 (Table 7) was found between the number of citations to papers and the number of papers. This suggests that an increase in citations reflects the importance of food security in developing countries.

5. Discussion and Conclusion

Examining the relationship between food security and various factors such as population growth, scientific development, GDP, patents, and research undertaken by different countries is crucial in today's society. This analysis focuses on studying the food security status of developing nations and its association with the number of patents, GDP, and research publications. Results demonstrate an upward trend in the publication and citation of scientific outputs in Iran, China, Japan, and South Korea. Additionally, China shows a better food production situation due to its higher number of patents and GDP. However, despite Japan's higher GDP, innovation, and paper count, it lags behind Iran and South Korea in terms of the food production index. Furthermore, Iran has a lower GDP than other countries, and South Korea's food production index is also comparatively lower.

In conclusion, our findings indicate a strong positive correlation between populations and papers counts in countries. Moreover, there is a reciprocal relationship between papers counts and GDP. Lastly, the correlation between the number of patents and papers suggests a strong positive relationship as well.

In general, these studies examined various aspects of food security in Iran and its relationship with different factors. Salimizadeh (2014) researched the food security strategy in Iran's economy and self-sufficiency in essential items. Allahiari and Zahighi Masuleh (2016) analyzed the relationships between scientific productivity indicators and human development indicators in Asia. Bagherzadeh Azar (2016) explored the state of food security in Iran and the effect of economic variables on it. Qaraizadeh (2016) focused on analyzing the future of food security in Iran. Heydari Chianeh et al. (2019) studied the impact of agricultural development on various dimensions of food security in developing countries. Sakhi, Hosseini, and Fatahi Ardakani (1400) analyzed the effects of international trade on food security. Winkler (2008) examined the correlation between the structure of scientific research, scientometric indicators, and GDP in EU and non-EU countries. Sovitlik (2018) researched the relationship between the level of economic growth and the state of food security worldwide. Manaf and Ismail (2019) investigated the relationship between food security and economic development. Bakudano and Countryman (2021) studied the impact of the

COVID-19 pandemic on GDP, food prices, and food security. Desh, Priyadarshini, and Dola (2023) focused on the dimensions of food security and the sustainability of organic agriculture.

These studies found that factors such as the ratio of urban to rural population, the area under grain cultivation, and the coefficient of irrigation under pressure in agricultural lands are effective in ensuring food security in Iran. They also highlighted the importance of strengthening the farm sector for employment and economic development in the country. Additionally, there is a strong correlation between the number of scientific outputs and the Hirsch Index, as well as between human development indicators, gross national product, and gender inequality. The studies emphasized the role of correct planning, favorable conditions in drivers and critical factors of food security, and government investment in the agricultural sector for achieving food security.

Iran has implemented policy strategies to improve food security, including the national knowledge-based document (2021) on food security. This document aims to create convergence and continuous movement towards food security, emphasizing the importance of knowledge-based approaches, research funding, and increasing the budget share for agricultural extension education. Monitoring indicators such as the contribution of total support to the agriculture and food sector from GDP and the contribution of agricultural research from research credits and GDP are also suggested.

It is evident that there is a positive relationship between scientific outputs, patents, GDP, and food security. Therefore, supporting applied research, preventing brain drain, and utilizing scientific research results are crucial for ensuring food security. To improve food security, policymakers should focus on correct scientific policy-making and planning, supporting scientific institutions, identifying capacities and threats, prioritizing applied research, promoting agricultural methods due to water scarcity, modeling from leading countries, and increasing self-sufficiency in food production. Other suggestions include improving nutritional literacy, creating research laboratories, supporting development projects, amplifying quality and health assurance systems, and changing import and export policies.

Further research should compare other countries using similar variables, explore additional factors related to food security, repeat the present study for comparison, and examine science, technology, and innovation policies' impacts on food security."

نشریه مطالعات دانش‌پژوهی

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