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Global Innovation Index: Comparative Study Of Saudi Arabia Versus G20 Countries

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ABSTRACT

This study analyzes Saudi Arabia's innovation performance over 12 years, using the Global Innovation Index (GII) to compare it with G20 countries. Innovation, essential for economic growth and competitiveness, is measured through input and output scores by the GII. Despite substantial investments, Saudi Arabia's innovation performance has fluctuated, showing growth from 2012 to 2014, a decline from 2014 to 2020, and a slow recovery from 2020 to 2023. Secondary data from GII reports were analyzed using E-views for Pearson correlation matrix calculations and DEA software for Data Envelopment Analysis. The findings reveal Saudi Arabia's commitment to innovation, evidenced by consistent investment in research and development. While the country's innovation ecosystem demonstrates room for improvement in converting inputs into tangible outcomes, Saudi Arabia shows a moderate positive correlation between inputs and outputs. The study highlights the need for Saudi Arabia to optimize strategies and processes to enhance Innovation efficiency. By benchmarking with high-efficiency G20 countries, Saudi Arabia can improve its innovation ecosystem and boost overall competitiveness and economic growth. This research is valuable for further studies and provides a foundation for policymakers and researchers to develop targeted strategies for sustained innovation performance improvements, aiming for a more robust and effective innovation system.

Keywords: Saudi Arabia, Global Innovation Index, Innovation Performance, Engineering Management, Economies Development, G20 Countries.

1.1. Introduction

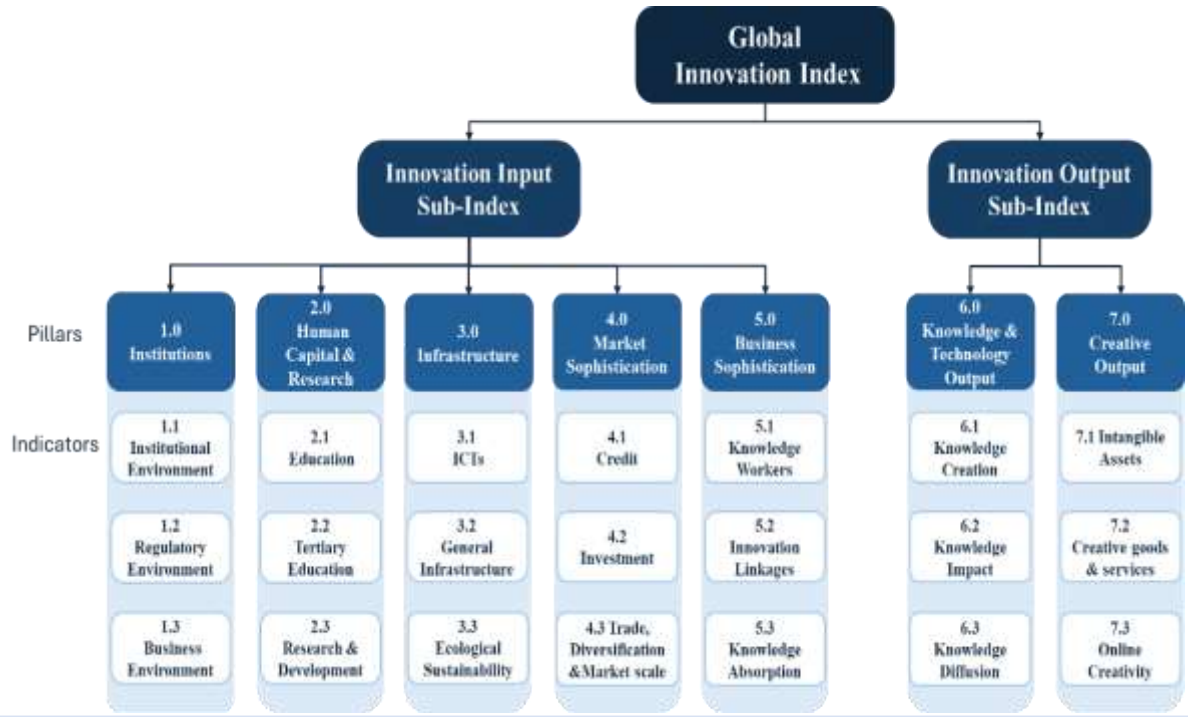
Innovation refers to any new idea, practice, or product that one adopts to enhance performance. According to (Hazen et al., 2012), innovation helps improve the quality of life for citizens and enhance the production and provision of services. As (Kovačević et al., 2021) noted, innovation aims to improve production and business capabilities, transfer knowledge and technology, and improve the country's competitiveness in the global market. Innovation plays a vital role in driving economic growth at the national and regional levels. It fosters economic development, raises wages, prolongs the product life cycle, enhances technology accessibility, elevates living standards, and introduces new organizational frameworks (Aytekin et al., 2022). Investing in innovation is essential for achieving a competitive edge. Innovation is a crucial indicator of a nation's competitiveness and is closely linked to economic growth. Therefore, to achieve higher economic growth, investing in innovation and promoting innovation activities is necessary (Yu et al., 2021). Investing in innovation activities has been found to positively impact a country's productivity, market efficiency, and Gross Domestic Product (GDP) (Carayannis & Grigoroudis, 2015).

Individual countries' innovation capability and efficiency levels are measured by the Global Innovation Index (GII) using input and output factors. Its primary objective is to aid policymakers, businesses, and other stakeholders in enhancing their ecosystems (Sohn et al., 2015). The GII has been calculated and co-published by the World Intellectual Property Organization (WIPO), Cornell University, and INSEAD since 2007. It is regarded as a tool that facilitates forecasting processes, enabling an understanding of the past, present, and future for measuring national competitiveness and revealing countries' comprehensive innovation performance (Wonglimpiyarat, 2010). The GII framework comprises input and output sub-indexes, as shown in Figure 1.1 (Dutta et al.,2020).

The Global Innovation Index (GII) is a highly respected and credible measure of a country's innovation performance and competitiveness. Since its inception in 2007, it has consistently provided reliable data on innovation performance, earning its reputation for reliability (Oturakci, 2021). The GII's methodology is transparent, well-documented, and well-suited to expert scrutiny and replication, making it a trusted source of information. The GII is developed and published by renowned institutions such as the World Intellectual Property Organization (WIPO), Cornell

University, and INSEAD, who bring their expertise to ensure the quality of the index. The accuracy and robustness of the GII are further validated by its rigorous peer review by experts in the field (Sohn et al., 2015). The GII is widely recognized globally as a benchmark for measuring innovation performance, and its findings and rankings have influenced policy decisions, demonstrating its impact and influence (Bate et al., 2023).

Figure 1. *Framework of the Global Innovation Index*



In a recent study, researchers examined how levels of innovation impact economic growth by analyzing Global Innovation Index (GII) rankings and various indicators over the past decade. They found that countries with high GII scores experienced strong economic growth due to high private R&D expenditure and knowledge-intensive employment. The study also revealed that economic growth in developed countries depended more on their innovation capability and scientific and technological development than in developing countries. The study proposed several policy recommendations based on these findings, including tailoring innovation strategies to every country's unique condition, enhancing technological innovation through university-industry collaboration, attracting investment, and improving national quality through educational reform and better support for

innovators. These recommendations aim to create an environment conducive to innovation, ultimately driving economic growth and improving global competitiveness (Xu, 2023).

In another study, the impact of innovation levels on economic growth was examined (Alkhanjari & Matriano, 2021), considering various factors contributing to changes in the Global Innovation Index (GII) ranking. The study identified several critical factors linked to GII through interviews with specialists and a questionnaire distributed to 204 respondents. These factors included fluctuating oil prices, the effects of the COVID-19 pandemic, insufficient R&D expenditure, data updating, availability issues, and delayed legislation enforcement. The findings emphasized the need for increased government spending on education, research, and innovation and better support for talented individuals and foreign investments to address these challenges effectively.

Additionally, Previous studies have underscored the critical importance of delving into the underlying dynamics between innovation inputs and outputs. These investigations have highlighted the necessity of understanding how the efficiency of innovation processes influences this relationship and, consequently, affects overall global innovation performance. By examining these fundamental connections, researchers can uncover the key factors that drive innovation success and identify potential areas for improvement in innovation strategies and policies (Nasir & Zhang, 2024).

1.2. Research Gap

Despite the research on global innovation performance, there still needs to be a significant gap in understanding the specific dynamics of Saudi Arabia's innovation performance relative to G20 countries. Existing studies have often documented the overall rankings and broad trends in innovation but have yet to delve deeply into the efficiency of innovation inputs and outputs in Saudi Arabia. Furthermore, there needs to be an evaluation of how well Saudi Arabia converts its innovation investments into tangible outputs compared to its G20 counterparts. This lack of detailed insight into the correlation between innovation inputs and outputs and the relative efficiency of these processes leaves a critical gap in the literature. Addressing this gap is essential to develop targeted strategies and policies to enhance Saudi Arabia's

innovation ecosystem and competitiveness in the global market. This research aims to fill this gap by providing a comprehensive and comparative analysis of Saudi Arabia's innovation performance, focusing on the efficiency and effectiveness of innovation investments over 12 years.

1.3. Significance

The finding of this research is significant because it will benchmark the innovation performance of Saudi Arabia against major economies. Moreover, provides a comprehensive assessment of innovation inputs and outputs, and enhances competitiveness and innovation ecosystem through Investments and partnerships in research, technology transfer, and capacity building. As well as guide strategic priorities and Policy Implications for economic diversification and development.

1.4. Purpose Statement

This study seeks to provide an in-depth analysis of Saudi Arabia's innovation performance compared to the G20 Countries in terms of Global Innovation Index (GII) score, inputs, and outputs scores. The scope of this study has been defined by the countries' scores over 12 years. This study is intended to bridge the existing knowledge gaps and offer evidence-based insights, to ensure sustained progress in innovation performance.

1.5. Research Objectives

- RO1: To compare Saudi Arabia's Innovation Performance with other G20 Countries.
- RO2: To determine the Correlation Between Innovation Input and Output Scores.
- RO3: To evaluate the Efficiency of Innovation Input on Innovation Output

1.6. Research Questions

- RQ1: How does Saudi Arabia's innovation performance compare to other G20 countries?
- RQ2: What is the correlation between the input and output scores of the Saudi Arabia and G20 innovation index?
- RQ3: To what extent is the efficiency of innovation input on the innovation output?

2. Methodology

This research used secondary data from the Global Innovation Index (GII) reports spanning 12 years, from 2012 to 2023, to analyze and compare Saudi Arabia's innovation performance against G20 countries. The GII provides comprehensive metrics on national innovation capabilities through input and output scores. This index is widely recognized for its credibility and robustness, making it an ideal source for this study. The analysis involved two main methodological approaches.

First, the Pearson correlation matrix examined the relationship between innovation input and output scores for Saudi Arabia and the G20 countries. This statistical analysis was conducted using E-views software, which facilitated the calculation of correlation coefficients, providing insights into the efficiency and effectiveness of innovation investments. The correlation matrix highlighted both positive and negative relationships, indicating areas where innovation inputs were successfully translated into outputs and where inefficiencies existed.

Second, the Data Envelopment Analysis (DEA) was used to assess the relative efficiency of innovation inputs on outputs. DEA is a non-parametric method used in operations research and economics to estimate production frontiers. It helps evaluate the efficiency of decision-making units (in this case, countries) in converting inputs into outputs. The DEA software was utilized to calculate the relative efficiency scores for Saudi Arabia and the G20 countries. This approach provided a comparative efficiency analysis, highlighting Saudi Arabia's performance relative to its peers.

By integrating these methodologies, the study provided a detailed analysis of Saudi Arabia's and G20's innovation performance. Using E-views for the Pearson correlation matrix allowed for identifying inefficiencies in innovation performance in terms of countries, while the DEA approach offered a comparative perspective on the overall efficiency of innovation inputs. This comprehensive methodological framework ensured a robust and insightful evaluation of innovation performance, contributing valuable findings to innovation studies.

3. Results and Discussion

3.1. Innovation Performance

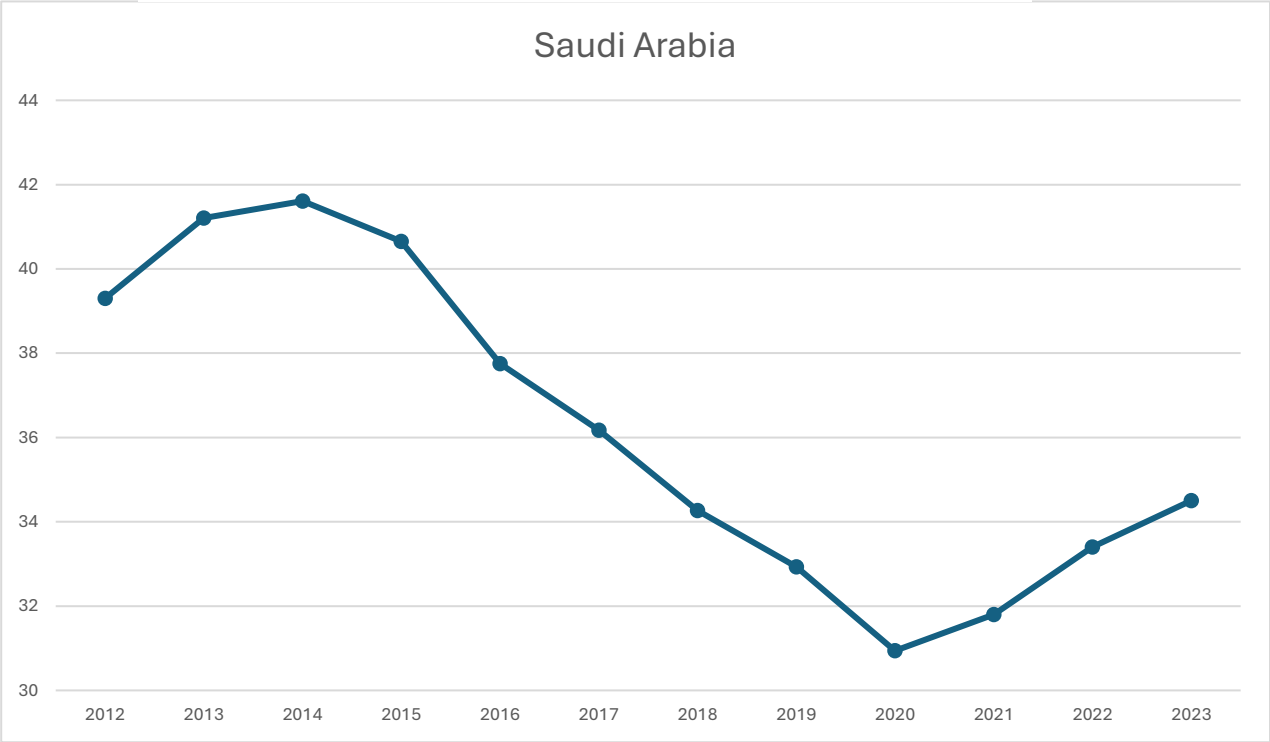
3.1.1. Saudi Arabia's Innovation Performance

Figure 3.1.1. illustrates Saudi Arabia's innovation performance over 12 years. Saudi Arabia showed commendable innovation performance from 2012 to 2014. During this period, the innovation performance index increased by approximately 5.88%, with an average annual growth rate of 2.94%. However, from 2014 to 2020, innovation performance fluctuated significantly and declined. The index dropped by 25.64%, translating to an average annual decrease of 4.27%. This period highlights notable volatility in Saudi Arabia's innovation performance.

In addition, between 2020 and 2023, Saudi Arabia's innovation performance showed signs of recovery. The index increased by 11.51%, with an average annual growth rate of 3.84%. This period, however, was still influenced by the effects of the COVID-19 pandemic, which impacted global innovation activities. From a holistic point of view, Saudi Arabia's innovation performance has seen an average annual fluctuation rate of approximately 4.16%. Notably, during the pandemic, from 2020 to 2023, the annual growth rate moderated to 3.84%.

Researchers and policymakers aim to increase the average annual innovation performance growth to exceed 4%. This ambition is significant when comparing Saudi Arabia's performance with other G20 countries with similar economic scales. Such comparisons will help determine a suitable and aspirational target for the country's innovation capabilities. Overall, Saudi Arabia's average innovation performance over the past 12 years is 36.21 out of 100. This indicates the importance of setting realistic and achievable goals for enhancing the innovation index, considering the historical data on fluctuations and trends.

Figure 3.1.1. *GII Score Over 12 Years for Saudi Arabia (KSA)*



3.1.2. Saudi Arabia's Innovation Performance Versus G20 Average Countries' Score

Figure 3.1.2. compares Saudi Arabia's innovation performance to the average scores of G20 countries from 2012 to 2023. From 2012 to 2014, Saudi Arabia's innovation performance index (GII) was consistently lower than the G20 average. However, Saudi Arabia's innovation performance increased from 39.3 to 41.61 during this period. Despite this improvement, the gap between Saudi Arabia and the G20 average remained approximately 5.5 points.

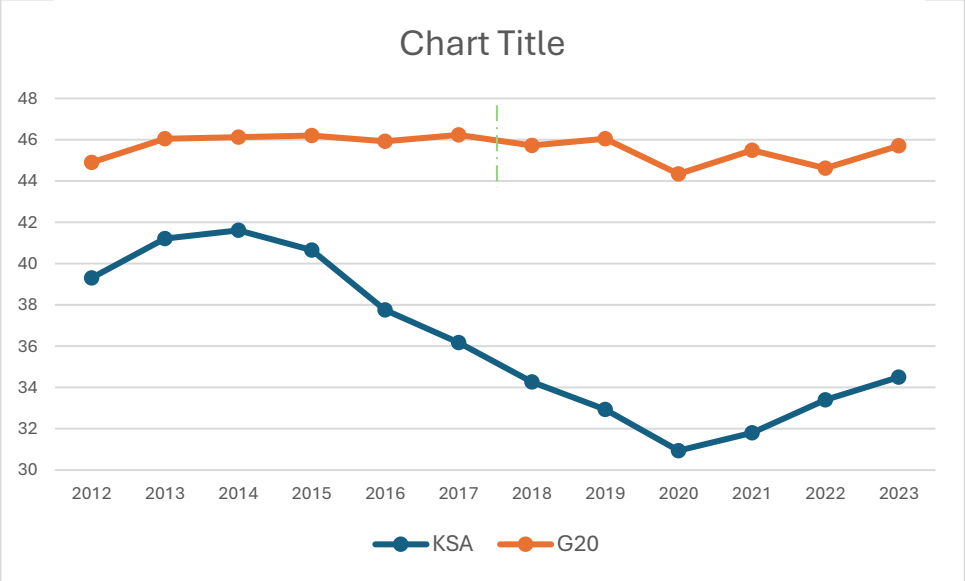
From 2014 to 2020, Saudi Arabia experienced a notable decline in its innovation performance index, which fell from 41.61 to 30.94. In contrast, the G20 average remained relatively stable, fluctuating slightly around the mid-40s. This resulted in an increasing gap between Saudi Arabia and the G20 average, reaching approximately 13.4 points by 2020, with an average annual decrease of about 4.82% for Saudi Arabia.

Additionally, from 2020 to 2023, Saudi Arabia's innovation performance showed signs of recovery, with the index rising from 30.94 in 2020 to 34.5 in 2023. Although the gap between Saudi Arabia and the G20 average remained, it reduced to approximately 11.2 points in 2023. This recovery period reflects an average annual

growth of approximately 3.70% compared to the 2020 index, indicating a positive trend despite the ongoing disparity.

Saudi Arabia's innovation performance index has consistently been lower than the G20 average for 12 years. However, the recent upward trend from 2020 to 2023 is promising. While the index remained below the G20 average, the annual growth rate of 3.70% since 2020 demonstrates Saudi Arabia's potential for continued improvement.

Figure 3.1.2. *Saudi Arabia (KSA)-G20 Innovation Performance*

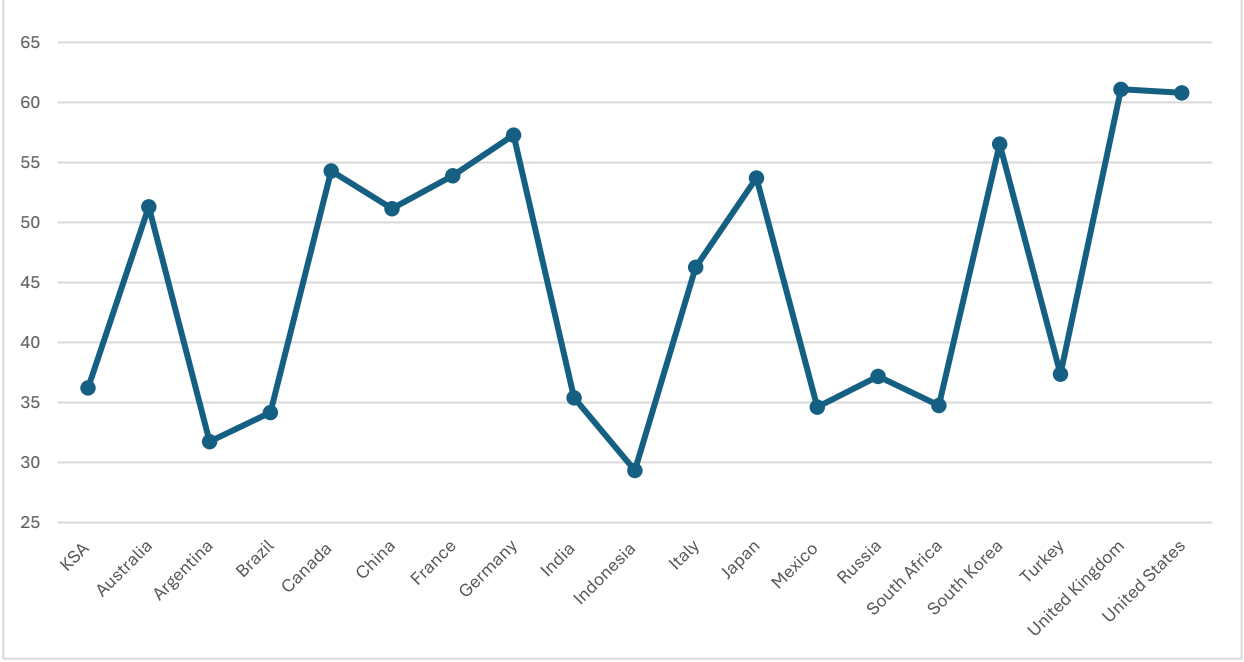


The mean plot of the innovation performance scores of G20 countries (**Figure 3.1.3.**) reveals a varied landscape with diverse innovation capabilities across nations. In a comparative context, the United Kingdom (mean score: 61.10) and the United States (mean score: 60.81) emerge as the leading nations in overall innovation performance. These high scores indicate robust innovation ecosystems with solid research and development infrastructure, significant technology investments, and supportive environments for startups and entrepreneurship. The advanced technological capabilities and favorable innovation policies contribute to their consistently high rankings. Germany (mean score: 57.29) and South Korea (mean score: 56.55) closely follow, recognized for their solid industrial foundations and emphasis on technological advancements. France (mean score: 53.91) and Japan (mean score: 53.72) also rank high, reflecting their longstanding commitment to innovation and substantial contributions to global technological progress. Canada (mean score: 54.30), Australia (mean score: 51.32), and China (mean

score: 51.15) fall into the excellent performer category. Australia benefits from its advanced educational system and strong research outputs, while China's rapid economic growth and significant R&D investments contribute to its innovation capabilities. Canada is supported by robust academic institutions. Italy (mean score: 46.27), South Africa (mean score: 34.76), Brazil (mean score: 34.16), and Mexico (mean score: 34.64) are classified as good performers. These nations have made notable progress in improving their innovative ecosystems. On the other hand, Argentina (mean score: 31.76) and Indonesia (mean score: 29.34) possess lower mean innovation performance scores within the G20. These scores reflect the ongoing challenges these nations face in research and development.

Saudi Arabia (mean score: 36.21) ranks among the good performers in the G20. However, there is a high investment in innovation input, which indicates the need to study the correlation between innovation input and output scores. Despite efforts to improve the country's innovation capabilities and invest in innovation inputs, it is essential to understand the relationship between these input scores and innovation output scores.

Figure 3.1.3. *Saudi Arabia (KSA)-G20 Innovation Performance: Compare Means Plot*



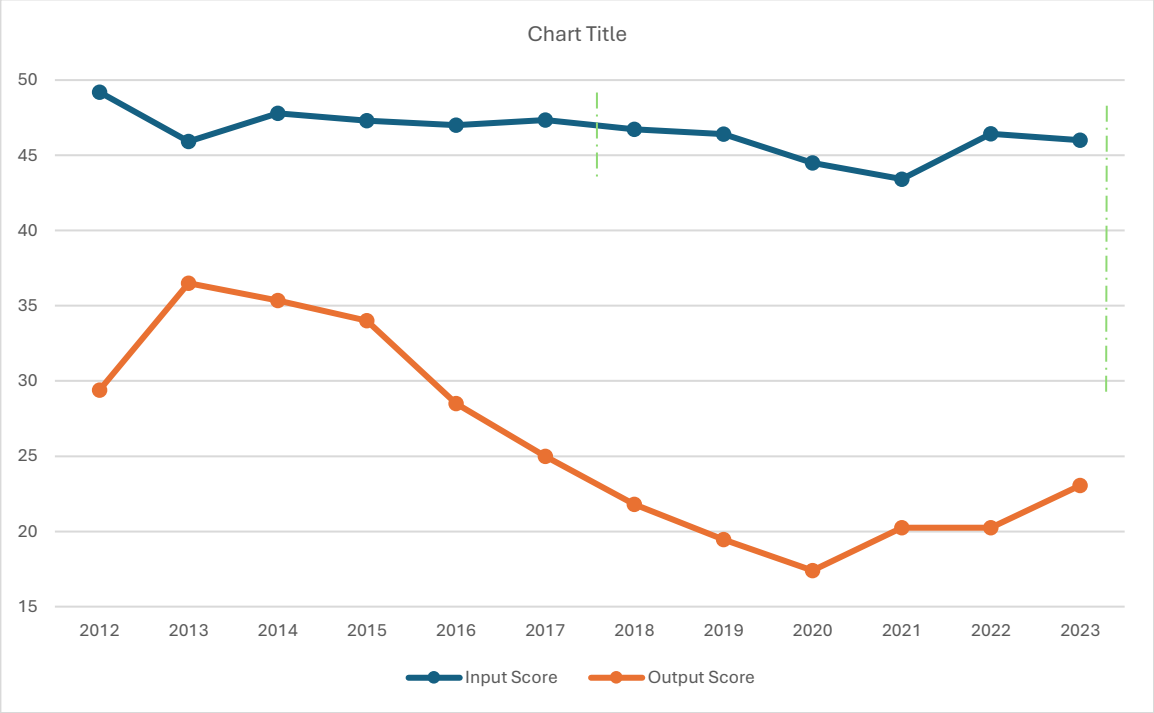
3.2. The Input and Output Correlation

3.2.1. The Correlation between the input and output scores of Saudi Arabia

Figure 3.2.1. illustrates the innovation input and output performance of Saudi Arabia over 12 years. From 2012 to 2023, Saudi Arabia's innovation input scores fluctuated slightly, with an average annual change of approximately -0.6%. The input score decreased from 49.2 in 2012 to 46.0 in 2023, demonstrating limited variation over the years. This steady trend in input scores suggests a consistent level of investment and resources dedicated to innovation. In contrast, the output scores exhibited a more significant and volatile trend, with an average annual change of -2.2%. The output score started at 29.4 in 2012, peaked at 36.5 in 2013, and then steadily declined to 17.4 by 2020. This notable decline indicates challenges in translating innovation inputs into practical outputs. However, from 2020 to 2023, there was a slow recovery, with the output score rising to 23.05 in 2023, signaling a potential improvement in the overall innovation performance.

Saudi Arabia's innovation input and output performance can be divided into three phases: Phase 1 (2012-2014) showed increasing outputs, reaching a peak in 2013; a prolonged decrease in outputs characterized Phase 2 (2014-2020) despite steady inputs; and Phase 3 (2020-2023) witnessed a slow recovery in outputs, suggesting potential positive trends for future innovation performance. Interestingly, in specific periods, such as 2012-2013 and 2020-2021, a decrease in input scores corresponded with an increase in output scores, indicating an inverse relationship between inputs and outputs in specific years. These findings highlight the importance of statistically analyzing the relationship between innovation inputs and outputs and comparing these with other G20 countries to identify peer nations. The recent positive trend from 2020 to 2023 is encouraging, indicating that Saudi Arabia can improve its input and output performance with the right strategies. For a comprehensive comparison, it is recommended that researchers focus on these three identified phases when evaluating Saudi Arabia's innovation performance against other G20 nations, paying particular attention to the most recent years (2020-2023) to sustain this positive momentum.

Figure 3.2.1. *Saudi Arabia: Input and Output*

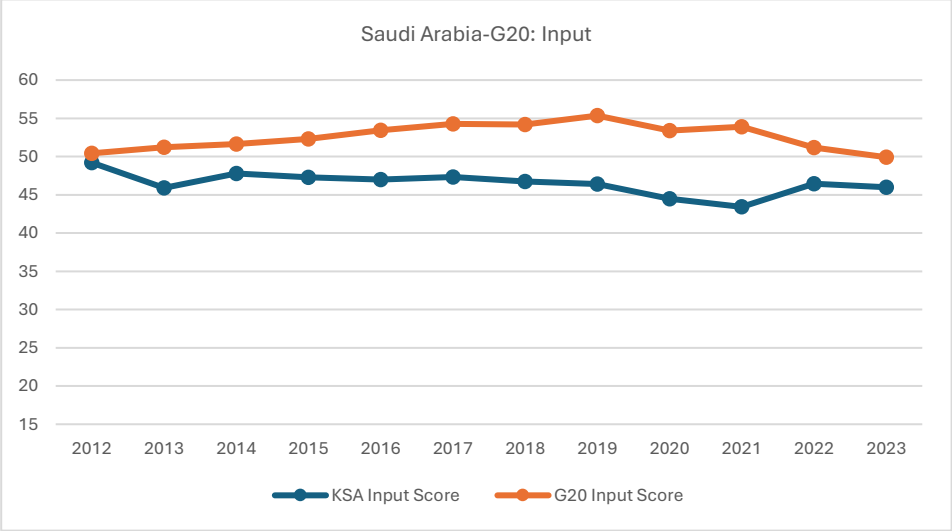


3.2.2. The Correlation between the input and output scores of G20

Input Scores

From 2012 to 2023, Saudi Arabia's innovation input scores were consistently lower than the G20 average, highlighting areas for potential improvement in innovation investment. In 2012, Saudi Arabia's input score was 49.2, 2.5% lower than the G20 average of 50.44. By 2019, the disparity widened significantly, with Saudi Arabia scoring 46.4 compared to the G20 average of 55.35, a difference of 16.1%. The lowest point for Saudi Arabia was in 2021, with an input score of 43.42, 19.5% below the G20 average of 53.91. Although there was a slight recovery in 2023 to 46.00, it remained 7.9% lower than the G20 average of 49.92. This consistent difference in performance, averaging a gap of 11.6% over the period, indicates a need for increased investment to match the G20 average level.

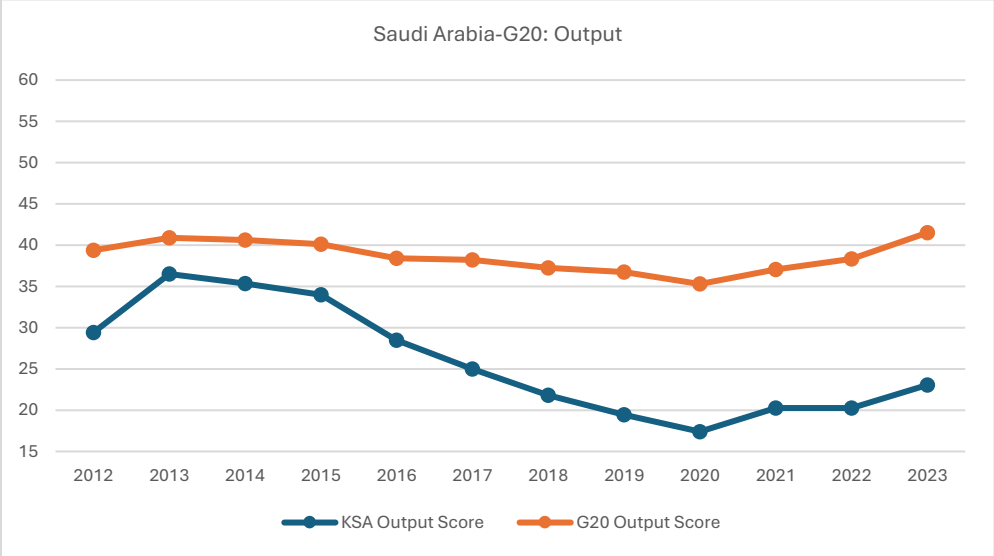
Figure 3.2.2.A. *Saudi Arabia (KSA) – G20: Input Performance*



Output Scores

From 2012 to 2023, Saudi Arabia's innovation output scores were consistently lower than the G20 average, highlighting challenges in translating innovation inputs into outputs. In 2012, Saudi Arabia's output score was 29.4, 25.3% lower than the G20 average of 39.36. This gap persisted and even widened over the years. By 2013, despite a peak in Saudi Arabia's score at 36.5, it was still 10.7% lower than the G20 average of 40.87. The disparity became more pronounced in subsequent years, with Saudi Arabia's scores declining significantly. In 2019, Saudi Arabia scored 19.46 compared to the G20 average of 36.73, a difference of 47%. The lowest point for Saudi Arabia was in 2020, with an output score of 17.4, 50.7% below the G20 average of 35.29. Although there was a slight recovery in 2023 to 23.05, it remained 44.5% lower than the G20 average of 41.50. This consistent performance difference, averaging a gap of 35.6% over the period, indicates a need for more effective strategies to convert innovation inputs into outputs and improve overall innovation performance.

Figure 3.2.2.B. *Saudi Arabia (KSA) – G20: Output Performance*



Overall, the correlation of Saudi Arabia's input and output scores in comparison with the G20 correlation between their input and output scores can be illustrated statistically by the Pearson correlation matrix as shown in Table 3.2.2.A. The Pearson correlation matrix reveals contrasting relationships between input and output scores for Saudi Arabia and the G20 countries. For Saudi Arabia, the correlation coefficient is 0.532, indicating a moderate positive relationship between input and output scores. This suggests that as innovation inputs increase, the outputs also tend to increase, although the relationship is not strong. This indicates some level of efficiency in converting inputs into outputs, but there is still room for improvement. Conversely, the G20 countries show a negative correlation coefficient of -0.761 between input and output scores, indicating a strong negative relationship. This suggests that as innovation inputs increase, the outputs do not correspondingly increase and may even decrease, pointing to significant inefficiencies in converting inputs into outputs. The negative correlation for the G20 highlights substantial challenges in translating innovation investments into tangible outcomes, more so than in Saudi Arabia. The contrasting correlations in these cases underscore the different dynamics within the innovation ecosystems of Saudi Arabia and the G20. For Saudi Arabia, while there is a positive relationship, the strength of this relationship needs enhancement. Improving the effectiveness of innovation strategies to ensure that increased investments in innovation inputs lead to proportional improvements in outputs is crucial. For the G20, addressing the strong negative correlation requires a

focus on identifying and mitigating the factors that cause inefficiencies in converting innovation inputs into outputs.

Table 3.2.2.A. Pearson Correlation Matrix: The input and output scores of Saudi Arabia & G20

Saudi Arabia (KSA)				**G20**			
Saudi Arabia (KSA)		Input	Output	**G20**		Input	Output
	Input	1			Input	1	
	Output	0.532	1		Output	-0.761	1

3.2.2. The Correlation between the input and output scores of G20 Countries

A negative correlation between innovation input and output scores indicates inefficiencies in converting innovation investments into tangible outputs. Among the G20 countries, Argentina shows a relatively weak negative correlation (-0.052), suggesting only slight inefficiencies. In contrast, Brazil exhibits a strong negative correlation (-0.672), highlighting significant challenges in translating innovation inputs into productive outcomes. Indonesia (-0.712) and India (-0.604) also face substantial inefficiencies, pointing to critical issues in their innovation strategies. Countries like Germany (-0.380) and Italy (-0.739) show moderate to strong negative correlations, indicating significant room for improvement in managing and utilizing innovation inputs. Russia (-0.286) and Turkey (-0.515) demonstrate moderate inefficiencies. With a very weak negative correlation (-0.227), South Korea suggests minor inefficiencies, indicating a relatively effective innovation system compared to other G20 countries. France (-0.315), Japan (-0.103), and the United Kingdom (-0.470) also exhibit varying degrees of negative correlations, indicating differing levels of inefficiency in converting innovation investments into outputs. The negative correlations across these countries underscore a common challenge: the need to optimize the conversion of innovation inputs into valuable outputs. Addressing these inefficiencies through strategic improvements in innovation processes can significantly enhance overall innovation performance and competitiveness. By adopting best practices and refining their innovation ecosystems, these countries can better leverage their investments to achieve more substantial and consistent innovation outputs.

Table 3.2.2.B. Pearson Correlation Matrix: The Negative Correlation input and output scores of G20 Countries

Argentina				**Brazil**				**Germany**			
		Input	Output			Input	Output			Input	Output
Argentina	Input	1		**Brazil**	Input	1		**Germany**	Input	1	
	Output	-0.052	1		Output	-0.6672	1		Output	-0.3800	1
Indonesia				**India**				**Italy**			
		Input	Output			Input	Output			Input	Output
Indonesia	Input	1		**India**	Input	1		**Italy**	Input	1	
	Output	-0.7112	1		Output	-0.6004	1		Output	-0.7399	1
Russia				**South Korea**				**Turkey**			
		Input	Output			Input	Output			Input	Output
Russia	Input	1		**South Korea**	Input	1		**Turkey**	Input	1	
	Output	-0.2866	1		Output	-0.2227	1		Output	-0.5155	1
France				**Japan**				**United Kingdom**			

France		Input	Output	**Japan**		Input	Output	**United Kingdom**		Input	Output
	Input	1			Input	1			Input	1	
	Output	-0.3155	1		Output	-0.1103	1		Output	-0.4700	1

There is a positive correlation between innovation input and output scores, indicating differing levels of efficiency in converting innovation investments into tangible outputs. China stands out with a strong positive correlation of 0.826, indicating that its innovation inputs are effectively translated into outputs, reflecting a highly efficient innovation ecosystem. Australia also shows a moderate positive correlation (0.457), suggesting a relatively efficient system where increased inputs lead to proportional outputs. The United States, with a correlation of 0.374, similarly demonstrates moderate efficiency in its innovation process. In contrast, countries like Canada (0.119) and Mexico (0.0928) exhibit weak positive correlations, indicating minimal efficiency in converting innovation inputs into outputs. South Africa (0.219) and Japan (0.150) also show weak correlations, suggesting room for improvement in their innovation processes. These insights underscore the importance of optimizing innovation processes to improve the conversion of inputs into valuable outputs. While countries like China and Australia exemplify efficient innovation systems, others with weaker correlations, such as Canada and Mexico, must refine their innovation strategies to better leverage their investments. Overall, the varying levels of positive correlation highlight the need for tailored approaches to innovation policy and investment to ensure that the resources dedicated to innovation are effectively converted into tangible outputs, thereby enhancing overall innovation performance and competitiveness.

Table 3.2.2.C. Pearson Correlation Matrix: The Positive Correlation input and output scores of G20 Countries		
Australia	**Canada**	**China**

Australia		Input	Output	**Canada**		Input	Output	**China**		Input	Output
	Input	1			Input	1			Input	1	
	Output	0.457	1		Output	0.119	1		Output	0.826	1
Mexico				**South Africa**				**United States**			
Mexico		Input	Output	**South Africa**		Input	Output	**United States**		Input	Output
	Input	1			Input	1			Input	1	
	Output	0.0928	1		Output	0.219	1		Output	0.374	1

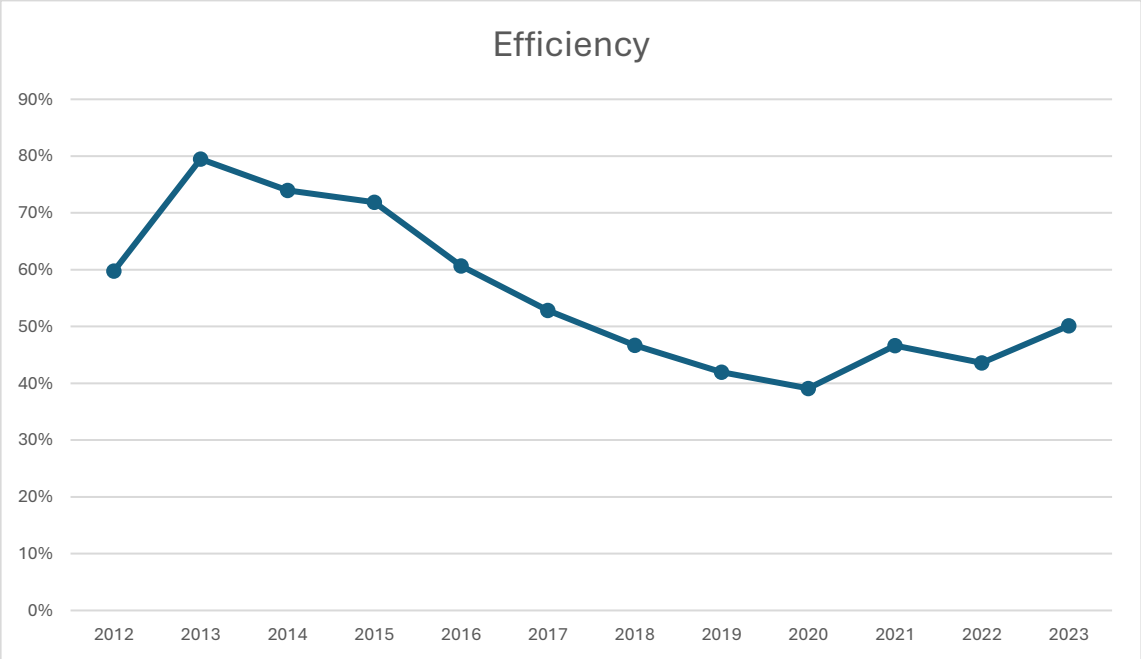
3.3. Efficiency of Innovation Input on Innovation Output

3.3.1. Saudi Arabia's Efficiency of Innovation Input on Innovation Output

The efficiency of innovation input on innovation output in Saudi Arabia from 2012 to 2023 shows significant variability. 2012, the efficiency rate was 60%. The highest efficiency was recorded in 2013 at 79%, indicating a peak period where the inputs were most effectively converted into outputs. However, this peak was followed by a decline, with efficiency dropping to 74% in 2014 and continuing to decrease over the subsequent years. By 2020, the efficiency rate had fallen to its lowest point at 39%. This period of decline highlights significant inefficiencies in the innovation process, where increased input is needed to enhance the outputs proportionally. From 2020 onwards, there were signs of recovery. The efficiency rate improved to 47% in 2021, slightly declined to 44% in 2022 and rose to 50% in 2023. This recent upward trend suggests that the country is making strides in addressing the inefficiencies in its innovation ecosystem. Over the three phases identified, Phase 1 (2012-2013) had an average efficiency of 69.5%, reflecting a period of growth with an average annual increase of

19%. Phase 2 (2014-2020) saw a steady decline, with an average efficiency of 55.4% and an average annual decrease of 5.83%. Phase 3 (2021-2023) shows a recovery, with an average efficiency of 47% and an average annual growth rate of approximately 1.5%. The fluctuating efficiency of innovation input on innovation output in Saudi Arabia underscores the dynamic nature of the country's innovation ecosystem. While there have been periods of high efficiency, significant declines highlight the need for continuous improvement and strategic alignment of innovation inputs and outputs. The recent recovery trend is promising, indicating that ongoing efforts to enhance the efficiency of innovation investments are beginning to yield positive results.

Figure 3.3.1. *Saudi Arabia: Innovation Efficiency*



3.3.2. Saudi Arabia's Relative Efficiency of Innovation Input on Innovation Output with G20

The relative efficiency of innovation input on innovation output for Saudi Arabia, when compared to the G20 average, provided valuable insights through the Data Envelopment Analysis (DEA) approach. Innovation input and output scores for Saudi Arabia in 2023 were recorded at 46.503 and 25.914, respectively, resulting in an input-output ratio of 0.557. In comparison, the G20 average input score was 52.603, with an output score of 38.642, yielding a higher input-output ratio of 0.735. Relative efficiency for Saudi

Arabia, calculated using the DEA approach, was determined to be 75.9%, with the G20 benchmark efficiency set at 100%. This analysis revealed that Saudi Arabia operates at 75.9% relative efficiency compared to the G20 average, indicating a 24.1% lower efficiency in converting innovation inputs into outputs. The lower input-output ratio for Saudi Arabia underscores the need for enhanced efficiency in its innovation processes. The potential for improvement in innovation outputs without necessarily increasing input levels is highlighted by this efficiency gap. Optimizing innovation strategies and processes can enable Saudi Arabia to better leverage existing investments.

Table 3.3.2. Saudi Arabia's Relative Efficiency of Innovation Input on Innovation Output with G20

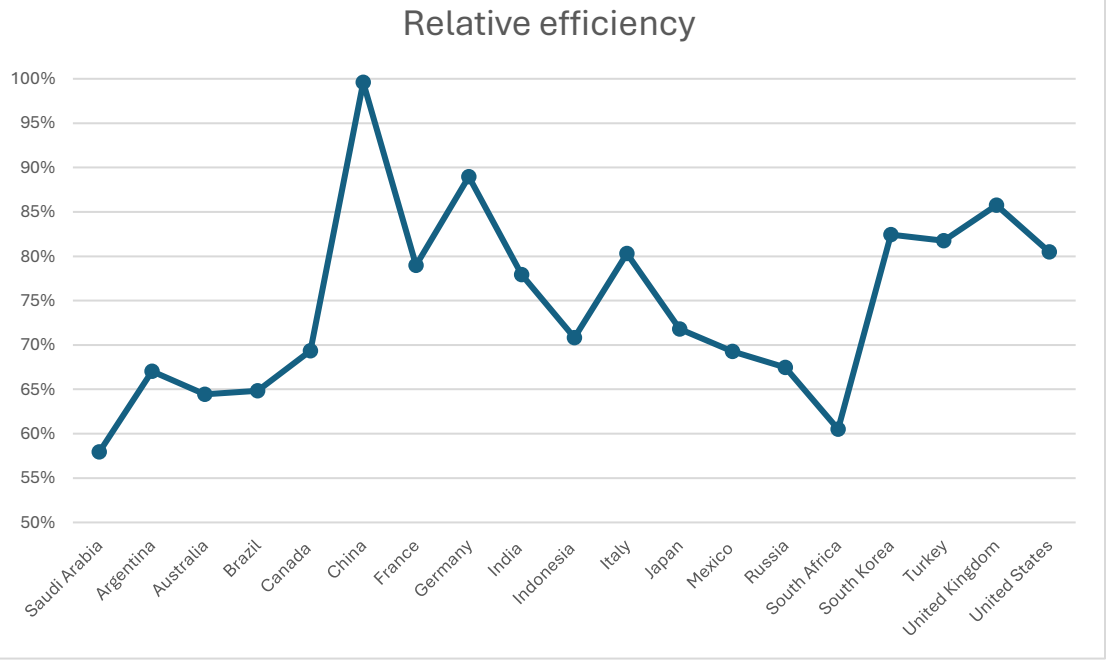
	Input	Output	Ratio	Relative Efficiency
Saudi Arabia	46.503	25.914	0.557	0.759
G20	52.603	38.642	0.735	1

3.3.3. G20 Countries' Relative Efficiency of Innovation Input on Innovation Output

The relative efficiency of innovation input on innovation output for G20 countries reveals significant variation in how effectively each country leverages its innovation investments. Calculated using the Data Envelopment Analysis (DEA) approach, these efficiencies highlight areas of strength and opportunities for improvement within each country's innovation ecosystem. With a relative efficiency of 58%, indicating considerable room for enhancing the effectiveness of its innovation inputs. In comparison, countries like China, which has achieved 100% relative efficiency, serve as benchmarks for optimal innovation performance. Other high performers include Germany (89%), South Korea (82%), the United Kingdom (86%), and the United States (80%), demonstrating their ability to convert innovation investments into substantial outputs effectively. Several G20 countries, such as Argentina (67%), Australia (64%), Brazil (65%), Canada (69%), and Mexico (69%), exhibit moderate relative efficiency, indicating a balanced yet improvable conversion of inputs to outputs. Italy (80%), Japan (72%), and Russia (67%) fall within this middle range, reflecting both their strengths and the need for strategic enhancements in

their innovation processes. Countries like South Africa (61%) and Indonesia (71%) show varying degrees of relative efficiency, suggesting that while there is some effectiveness in their innovation ecosystems, significant opportunities for improvement remain. Turkey (82%) and India (78%) exhibit higher efficiencies. The diverse range of relative efficiencies across the G20 underscores the importance of tailored strategies to improve innovation performance. By analyzing the practices of high-efficiency countries and addressing specific inefficiencies, countries with lower relative efficiencies can enhance their innovation outcomes, thereby boosting their overall competitiveness and economic growth.

Figure 3.3.3. *Saudi Arabia (KSA) – G20 Countries': Relative Efficiency*



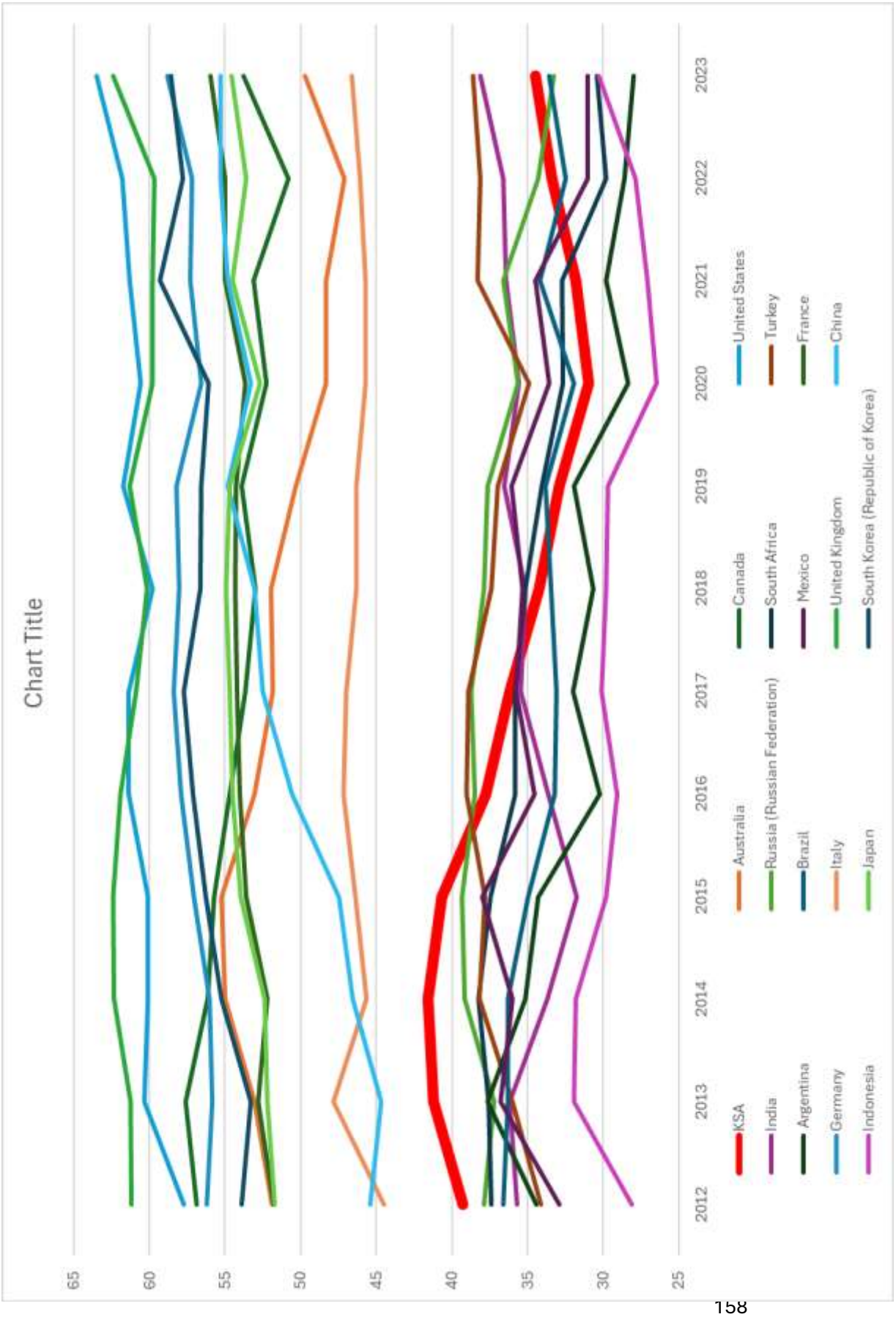
4. Conclusion

This research provides a comprehensive analysis of Saudi Arabia's innovation performance compared to G20 countries using the Global Innovation Index (GII). The findings highlight that Saudi Arabia has made significant strides in enhancing its innovation capabilities, with notable efforts reflected in its recent performance recovery. Although Saudi Arabia currently lags behind G20 averages in innovation inputs and outputs, the analysis reveals a positive trajectory and substantial potential for growth. Over the past 12 years, Saudi Arabia's innovation performance has experienced fluctuations, characterized by periods of growth,

decline, and a promising recovery. The study acknowledges that while there have been inefficiencies in converting innovation inputs into outputs, the recent upward trend is encouraging. By addressing these inefficiencies and optimizing innovation strategies, Saudi Arabia can further enhance the effectiveness of its innovation processes. Learning from the successful practices of high-efficiency G20 countries, Saudi Arabia can better leverage its substantial investments to achieve more consistent and substantial innovation outputs. Continuous improvement and strategic alignment of innovation inputs and outputs are crucial for sustaining and enhancing the country's competitiveness in the global market. Through targeted efforts and strategic improvements, Saudi Arabia is well-positioned to bridge the gap with G20 nations and foster a more robust and effective innovation ecosystem. The positive momentum and commitment to innovation provide a strong foundation for future growth, ensuring that Saudi Arabia can achieve its ambitious goals and contribute significantly to the global innovation landscape.

5. Appendices

Figure 5. *Saudi Arabia (KSA)-G20 Countries Innovation Performance*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Germany
Indonesia
Australia
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Brazil
Italy
Japan
Canada
South Africa
Mexico
United Kingdom
South Korea (Republic of Korea)
United States
Turkey
France
China

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