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ASSESSING THE IMPACT OF INNOVATION ON EGYPT'S ECONOMIC GROWTH DURING CRISIS AND MAJOR EVENTS

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Abstract. This paper aims to analyze and track the impact of innovation on economic growth in Egypt in light of the crises, risks, and events that Egypt went through from 2011 to 2020. It also aims to identify the innovation indicators that most impacted economic growth during the study years. The study examines how innovation acts as a catalyst for economic development in light of political, social and economic turmoil, including economic reforms and external shocks in the aftermath of the 2011 revolution. The research relied on a field study of the innovation and entrepreneurship community in Egypt through a survey conducted on partners and beneficiaries of the National Technology Incubators Program "INTILAC", which is one of the programs of the Academy of Scientific Research and Technology, which supports innovators, entrepreneurs and start-ups whose ideas are based on an innovative and technological component. The research uses the STEEP (Social, Technological, Economic, Environmental and Political) analysis framework to identify the obstacles and crises that Egypt went through and that had a comprehensive impact on innovation activity. The results showed a significant and direct impact of innovation on the growth of per capita GDP annually during the study years in the short and long term. The study relied on 5 sub-indicators representing innovation, namely the index of the percentage of spending on research and development as a percentage of GDP, the index of the size of the local market and market development, the index of the number of peer-reviewed scientific articles published in journals, the index of the percentage of high-tech exports from total manufactured exports, and the index of the number of patent applications for residents, versus the index of the growth rate in per capita GDP annually as an expression of economic growth. The study concludes with recommendations to strengthen the relationship between innovation and economic growth, which contributes to building a more flexible and competitive Egyptian economy.

Keywords: Innovation; Economic growth; Crises; Entrepreneurship

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1. Introduction

The concept of innovation has been understood and defined in various ways by different researchers, writers, and experts. It is often described as the introduction of new or significantly improved products (either goods or services), processes, marketing techniques, or organizational methods in business practices, workplace arrangements, or external relations. Additionally, innovation is seen as the outcome of advanced research and development, which leads to new industrial products and services, as well as improvements in marketing approaches and work organization (Oslo Manual, 2018). Innovation is widely recognised as a fundamental driver of economic growth and long-term prosperity. The capacity to generate and apply new ideas, technologies, and processes enables economies to enhance productivity, create new markets, and improve living standards

(Dempere et al., 2023). Given the importance of innovation in the fierce race between the countries of the modern and ancient worlds, all countries have given importance to them, allocated a share of the gross domestic product to spend on them, and developed various strategies and programs to support them, there have been many local, international and regional entities supporting innovation (Fartash & Darehshiri, 2022; Hutschenreiter et al., 2019). Developed countries view innovation as a key driver of economic growth, which fosters comprehensive and sustainable development. Consequently, economic growth enhances living standards by increasing the production of goods and services, improving their quality, and adding competitive advantages (Mohamed et al., 2022). Technology, a cornerstone of innovation, also plays a critical role in economic growth, as it serves as a production input—whether in the form of new products or innovations in production techniques. This leads to improved production efficiency, reduced costs, and the addition of competitive product features, which opens new markets and indirectly increases invested capital (McManus, 2020).

1.1. The Role of Innovation in Economic Growth

Economic growth is a "continuous phenomenon", not a temporary or occasional. Economic growth is defined as the continuous increase over a period or several long periods of an economic indicator, often the gross domestic product per capita. (Alcouffe, 2022; Caloffi & Serra, 2022). The American scientist Joseph Schumpeter also distinguished between economic growth and economic development, where he acknowledged from his point of view that economic growth represents a slow and gradual change in the economic system due to factors external to this system, while he saw that economic development is generated through intermittent internal changes resulting from economic innovations (Becker et al., 2012). Information technology currently plays a distinct and important role in the economy at all levels, local, regional and international, after traditional economic thought had been based for a long time on the concept of the availability of natural resources and their ability to enhance production, which in turn is the engine of the global economy, and also as a pillar of economic development, especially after the emergence of the industrial revolution (Daher et al., 2023). The concept of the knowledge economy has emerged, which means the emergence of new economic resources alongside traditional resources, which is called information technology, considering that information is one of the items of capital considering existing economic concepts, which are considered an economic resource that generates a return in a tangible or intangible manner (Koretska, 2022).

The knowledge economy is characterized as an economy capable of acquiring, creating, disseminating and applying knowledge to promote development. The knowledge economy also depends on the availability of information and communications technology and uses innovation and digitization to produce goods and services with high added value (Isametdinovna, 2022).

The relationship between economic growth and innovation has garnered significant attention from researchers in economics (Qizi and Karimovna, 2024; Jiang et al., 2022). Innovation directly and profoundly affects production capacity, promoting sustainable economic development and boosting overall GDP (Shi et al., 2024). It is widely accepted that innovation significantly enhances productivity and competitiveness, enabling sustainable economic growth through improved efficiency, reduced costs, and expanded market opportunities (Kubitskyi et al., 2024). The relationship between innovation and growth is especially important for developing countries like Egypt, where structural challenges such as high unemployment, dependence on low-value-added industries, and income inequality hinder economic progress. Investment in innovation, particularly in research and development (R&D), education, and entrepreneurship, can help emerging economies overcome these barriers. For Egypt, fostering innovation is a means of improving economic performance and a pathway to social and economic resilience. (Kumar et al., 2024; Duarte, 2013)

The relationship between economy and innovation is rooted in the resources available to fund education, R&D, entrepreneurship and infrastructure (Boțoroga et al., 2022). As economies grow wealthier, they can allocate more

to these areas, creating a virtuous cycle of innovation that further drives economic development. According to the data presented in the Global Innovation Index 2020 (GII), there is a clear, predictable pattern: the more developed an economy is, the more it innovates. Figure 1 reflects the positive correlation between an economy's GDP per capita and GII score, indicating that high-income economies typically outperform their lower-income counterparts in innovation performance.

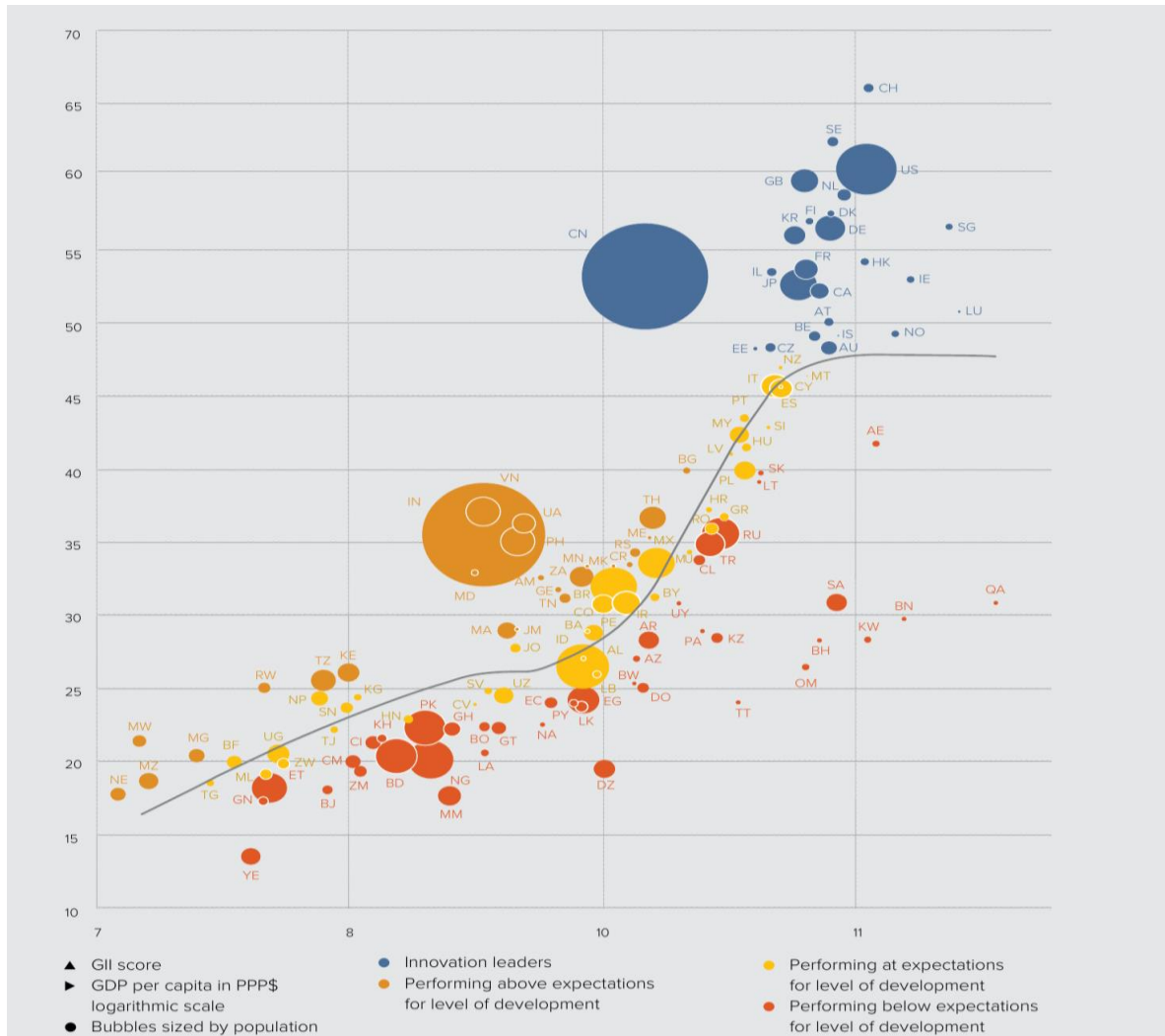


Fig. 1. The positive relationship between innovation and development (GII 2020)

Source: WIPO, 2024

Between 2011 and 2020, Egypt experienced significant political and economic challenges, sparking debates about how these upheavals affected the country's innovation initiatives and economic development. Egypt experienced significant social and political upheaval, beginning with the 2011 revolution. While the revolution brought political change, it also led to prolonged instability, significantly impacting Egypt's economy. (James, 2015). During this time, Egypt faced declining foreign direct investment, declining tourism revenues, high unemployment rates, and a deteriorating fiscal position, alongside global economic volatility and domestic policy missteps. Amid these challenges, innovation has emerged as a potential driver of economic recovery, although its full potential may be limited by the prevailing instability (Elbargathi, 2019).

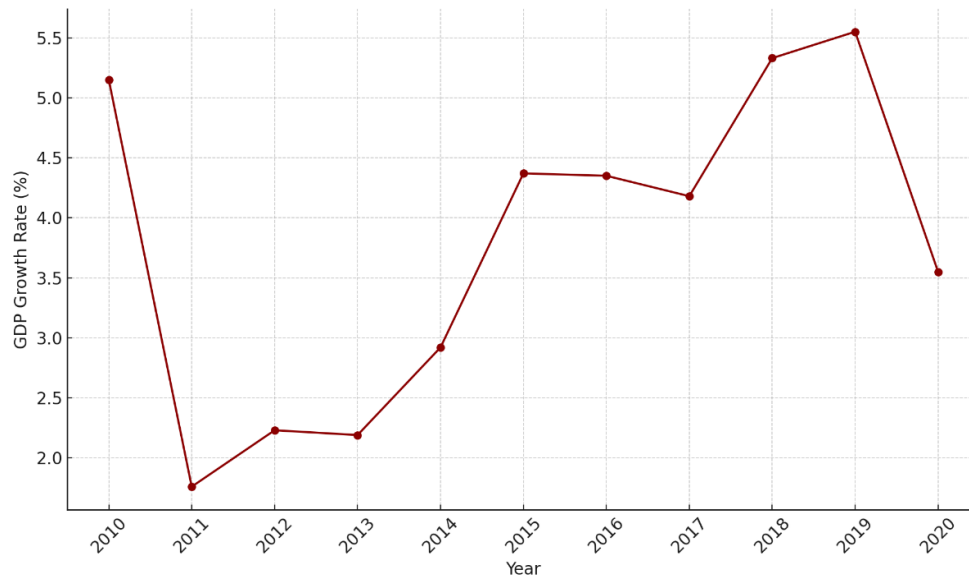


Fig. 2. Egypt's GDP Growth Rate (2010-2020)

Source: World Bank Open Data, 2024

Figure 2 shows Egypt's GDP growth rate from 2010 to 2020 and how political events, economic policies, and external shocks, such as the global pandemic, have shaped Egypt's economic trajectory, showing periods of contraction and recovery. After a strong growth rate of 5.15% in 2010, the Egyptian revolution in 2011 led to a sharp decline to 1.76%, driven by political instability, a decline in tourism, and a decline in foreign investment. The period between 2012 and 2014 saw a slow recovery as political uncertainty persisted, with growth rates hovering around 2%. However, starting in 2015, Egypt began implementing fundamental economic reforms, such as devaluing the currency and cutting subsidies, which led to a gradual improvement in growth. By 2018 and 2019, the economy had grown significantly, driven by increased foreign investment, a thriving energy sector, and rising domestic demand, achieving growth rates of over 5%. However, the COVID-19 pandemic in 2020 caused growth to slow again, with growth falling to 3.55% due to a sharp decline in tourism, a decline in exports and a rise in unemployment. Despite this setback, the Egyptian economy has shown resilience, supported by previous structural reforms, diversification efforts and the implementation of a reform program in cooperation with the International Monetary Fund (World Bank Open Data, 2024)

1.2. Innovation Landscape in Egypt: 2011–2020

The innovation landscape in Egypt from 2011 to 2020 experienced substantial growth, supported by governmental and international initiatives to enhance digital transformation, entrepreneurship, and technology-driven economic sectors. Despite the political and economic challenges, Egypt's innovation landscape showed resilience and gradual improvement during this period. Several sectors, particularly information technology, renewable energy, and healthcare, demonstrated significant innovation potential, driven by both public and private investments. One of the key indicators used to assess a country's innovation performance is the Global Innovation Index (GII), which ranks nations based on factors such as institutions, human capital, research and development, infrastructure, and market development (WIPO, 2020). These metrics provide insight into a country's ability to foster a sustainable environment for innovation. In Egypt's case, the GII ranking from 2010 to 2020 highlights challenges and progress in the country's innovation landscape (Figure 3). Following the political turmoil in 2011, Egypt's ranking initially worsened, with a significant drop as the country grappled with instability and economic

disruption. However, from 2012 onwards, Egypt began to rebuild its innovation capacity, particularly in sectors like information technology, entrepreneurship, and renewable energy.

By 2017, Egypt had reached its best GII performance, supported by investments in ICT and education reforms. The country continued to push forward, with notable improvements in digital infrastructure and innovation ecosystems. Although the GII ranking fluctuated between 2018 and 2020, with a slight decline towards the end of the decade, the overall trend reflects a resilient innovation landscape that benefited from both public and private investments. Egypt's focus on emerging sectors, such as FinTech and renewable energy, played a significant role in this gradual improvement, positioning the country as an emerging hub for innovation in the MENA region (Egypt Today, 2021).

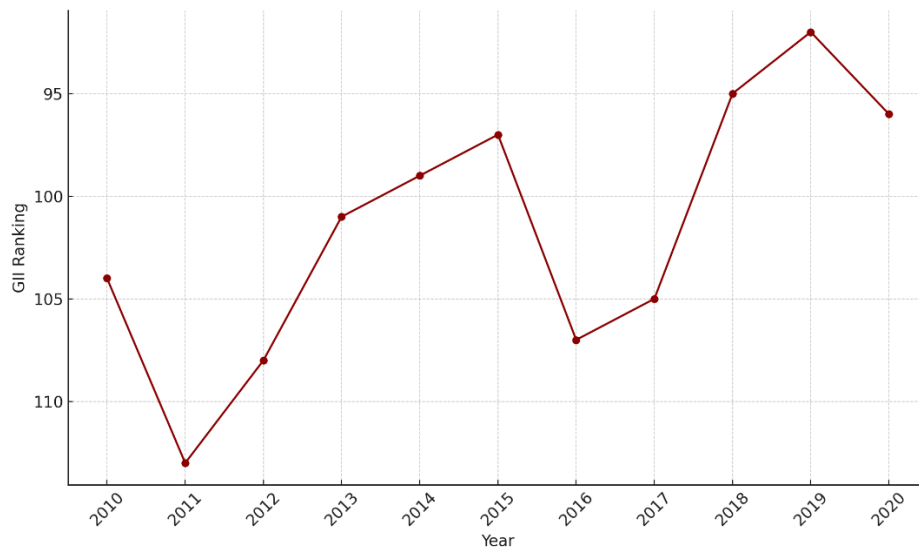


Fig. 3. Egypt's Global Innovation Index Ranking (2010-2020)

Source: WIPO, 2024

Innovation remains the most risky activity because it deals with the non-existent, the non-existent, the completely unknown and the ambiguous in the idea and the application (method, product, process) with a high probability of failure and failure, meaning that innovation is a process saturated with risk the more the serious idea advances in the stages of application (production) and moves to the market (Lou et al., 2021; Nemeth, 1997). The success of efforts to enhance innovation is highly dependent on the coordinated actions of various entities and the interactions between them. Additionally, these efforts are shaped by the unique economic and social factors characteristic of each specific economy (Nawrocki & Jonek-Kowalska, 2022; Gupta, 2021; Alarcón et al., 2018).

The concepts of innovation and crises share the fact that each carries within it an element of surprise and risk, as each represents a departure from the familiar and the familiar and dealing with the unknown, the unknown and the unexpected (Sharma et al., 2022). In this regard, Egypt has gone through many crises and events from 2011 to 2020, which affected all society activities in general and innovation activity in particular. This study uses a PESTEL analysis to explore the key factors affecting innovation in Egypt during this period. The PESTEL framework examines Political, Economic, Social, Technological, Environmental, and Legislative influences that shaped the environment. These factors played a role in enabling or hindering innovation activities, with some contributing positively and others acting as barriers. By understanding how these external forces impacted innovation, this analysis provides insights into the broader socio-economic landscape of Egypt during a decade of

transformation. The central question of this study is, "What is the impact of innovation on economic growth in Egypt, considering the challenges and crises that Egypt went through in the period from 2011 to 2020?" Moreover, "Which of the selected sub-indicators of innovation had the greatest impact on economic growth from 2011-2020?" This paper seeks to answer these questions by analyzing the Egyptian economy's innovation landscape and the factors that influenced its performance during a crisis.

2. Hypothesis

The hypotheses in this study are grounded in the framework of "endogenous growth theory" particularly inspired by Paul Romer's seminal work on technological change, emphasizing that technological progress results from intentional investments in research and development (R&D), human capital, and innovation by firms and individuals within the economy. Unlike earlier models that viewed technological advancement as exogenously driven, Romer argued that internal factors, such as knowledge creation and technological advancement, are key drivers of sustained economic growth (Romer, 1990). This paper examines how these internal factors, represented through various innovation indicators such as R&D expenditure, technological output (high-tech exports and patents), knowledge creation (scientific publications), and market development, contribute to economic performance. Given Egypt's political, social, and economic challenges between 2011 and 2020, the relationship between innovation and economic growth may exhibit varying strengths, depending on the specific indicator examined. This period witnessed significant economic reforms, external shocks, and social turmoil, necessitating a deeper exploration of how innovative activities can stimulate long-term economic growth.

The main hypothesis proposed in this paper is that there is a statistically significant relationship between innovation and economic growth in Egypt. This is further broken down into several sub-hypotheses. The first sub-hypothesis suggests a significant relationship between the growth in research and development (R&D) expenditure, as a percentage of GDP, and the annual growth in GDP per capita. The second sub-hypothesis focuses on the number of patent applications by residents, proposing that it correlates with GDP per capita growth. The third sub-hypothesis examines the role of high-tech exports, positing a significant link between the percentage of high-tech exports from total manufactured exports and economic growth. The fourth sub-hypothesis explores the relationship between the number of peer-reviewed scientific publications and annual GDP per capita growth. Finally, the fifth sub-hypothesis suggests that the size and development of the local market are significantly related to economic growth in Egypt.

3. Methodology

The primary objective of this study is to explore the relationship between innovation and economic growth in Egypt from 2011 to 2020, with a focus on understanding how the political and economic crises of the period affected this relationship. The study employs a combination of qualitative and quantitative methods to examine Egypt's innovation landscape, including an analysis of key innovation indicators.

3.1. Data Collection

The data used in this study was obtained from a variety of sources, including the World Bank, the Global Innovation Index, the IMF, and Egyptian government reports. In addition, qualitative data was collected through a field study involving partners and beneficiaries of the "INTILAC" National Technology Incubators Program, managed by the Academy of Scientific Research and Technology. This program supports innovative and technological ideas. A sample of 100 participants was selected, and 91 completed questionnaires were deemed sufficient for the analysis. The survey sample consisted of 67.0% participants from the age group above 40 years, while 22.0% were from the age group 30-40 years, and 11.0% belonged to the 20-30 age group. In terms of gender distribution, 58.2% of the sample were male, and 41.8% were female. When considering educational

qualifications, 41.8% of the participants held a PhD, 38.5% had a master's degree, and 19.8% held a university degree. Regarding work experience, 80.2% of the sample had more than 10 years of experience, 12.1% had 5-10 years of experience, and 7.7% had 0-5 years of experience.

3.2. Study Design

A questionnaire was developed as the primary tool for data collection, structured into two main sections. The first section focused on gathering demographic information about the participants, including their gender, age, education level, years of experience, role, type of organization, and geographic location. The second section comprised 45 items distributed across several variables. The independent variable, innovation, consisted of 18 items measuring five Sub-indicators of innovation: research and development expenditure, intellectual property and patents, technological exports, scientific publications, market competition, and the number of registered startups. The dependent variable, economic growth, included eight items assessing the growth rate in per capita GDP.

Additionally, 17 items addressed the crises and challenges Egypt faced during the study period, focusing on political, economic, social, technological, environmental, and legislative factors. Five innovation indicators were selected to analyze their influence on economic growth: the percentage of GDP spent on research and development, the size and development of the local market, the number of peer-reviewed scientific publications, the percentage of high-tech exports, and the number of patent applications by residents. These indicators were then analyzed in relation to annual growth in per capita GDP to assess their overall impact on economic development.

3.3. Analytical Approach

The study employs regression analysis to estimate the relationship between innovation indicators and economic growth; specifically, the study used the Autoregressive Distributed Lag (ARDL) model to test the hypotheses and the Jarque-Bera normality test to verify the normal distribution of the data. Additionally, correlation matrices and tests for autocorrelation (using Durbin-Watson) were applied to ensure the validity and reliability of the results.

4. Results and Discussion

4.1. PESTEL for Events and Crisis

The research utilised a PESTEL analysis to examine the broad range of factors influencing innovation activities; it assessed political, economic, social, technological, environmental, and legal components, emphasizing how both internal and external influences affected Egypt during the period from 2011 to 2020. The analysis was grounded in a review of existing literature as well as insights from industry experts, as outlined in Table 1.

Table 1. PESTEL Analysis for Events and Crises in Egypt (2011-2020)

Political Factors	Economic Factors
- The Arab Spring of 2011 had a profound impact on Egypt's political landscape, resulting in periods of instability and government changes. These shifts brought both advantages and challenges to the country's innovation efforts. - Egypt's commitment to regional partnerships, such as its involvement in the African Continental Free Trade Area (AfCFTA), opened up new markets and promoted cross-border innovation (Abdulghany, 2020). - In March 2015, Egypt introduced its plan for addressing future challenges, known as "Egypt's	- The state of economic collapse and instability in Egypt after the 2011 revolution until late 2014, which is the period after the 2011 revolution and the rule of the Brotherhood in Egypt. - In 2016, Egypt undertook significant economic reforms, including the devaluation of the Egyptian pound and the implementation of an IMF-backed economic reform programme, also increasing inflation, impacting consumer purchasing power and funding availability for startups. The program also included fiscal tightening and the adoption of a

Vision 2030." This 2030 Sustainable Development Strategy (SDS) highlights key sectors crucial for Egypt's long-term growth and sets the framework and guidelines to achieve the nation's developmental goals (Omran & Negm, 2022). Egypt's National Strategy for Science, Technology, and Innovation (STI) was officially launched in 2016. This strategy is part of Egypt's broader efforts to enhance its research and innovation capacity, in alignment with the Egypt Vision 2030 framework for sustainable development (Radwan & Sakr, 2017).	floating exchange rate (Binh, 2024) - By 2020, internet penetration in Egypt surpassed 50%, reaching 54%, which significantly boosted sectors like e-commerce, online learning, and telemedicine. This digital transformation created a fertile ground for tech-driven innovation. (Kemp, 2020). - The 2014 constitution placed greater emphasis on scientific research and innovation, mandating increased government spending on research and development (R&D), leading to more opportunities for innovation across sectors.
Social Factors	Technological Factors
2011-2013: There was an increase in youth unemployment due to political instability in the country, combating terrorism and addressing crises. - Demographic changes, particularly Egypt's large and growing youth population, contributed to an increase in demand for technological solutions, mobile applications, and education reforms that promoted innovation. - Social attitudes towards entrepreneurship have shifted positively, with more young Egyptians pursuing startups and technological innovations. - The increased role of women in technology and entrepreneurship has contributed to broader social innovation and gender inclusivity in the workforce.	- Government-led initiatives, like "Digital Egypt" and investments in IT infrastructure, have enhanced the nation's technological capacity, contributing to increased innovation. - The rise of innovation hubs and incubators, such as Flat6Labs, provided support for tech startups and fostered a culture of entrepreneurship. - Growth in sectors such as ICT and renewable energy spurred innovation, particularly as Egypt aimed to diversify its economy. - The launch of 4G networks and efforts to introduce 5G in the coming years further facilitated innovation, particularly in mobile applications and smart technologies. - The increasing adoption of digital platforms, mobile banking, and e-commerce, especially during and after the 2020 COVID-19 pandemic, is accelerating innovation in these fields.
Environmental Factors	Legal Factors
- The government's commitment to renewable energy projects, such as the Benban solar farms, has boosted innovation in the energy sector. - Global concerns about climate change have prompted Egypt to explore green technology solutions and raise environmental awareness in the business sector. - In 2019, Egypt and the world faced one of the most severe health crises the world has ever witnessed, namely the COVID-19 pandemic and its consequences, which began in 2019, and we are still suffering from its consequences to this day. - The challenges of water scarcity have led to the development of innovative irrigation technologies and water management systems, especially in agriculture. - Egypt's participation in international environmental agreements, such as the Paris Climate Agreement, has prompted the country to adopt greener technologies, reduce carbon emissions, and promote innovation in clean	- Reforms in intellectual property rights (IPR) laws and enforcement improved protection for innovators and boosted investor confidence, particularly in the tech and pharmaceutical sectors. - Egypt's new investment law passed in 2017, simplified bureaucratic processes, encouraging foreign and local investment in innovation-driven sectors. - The government's introduction of legislation promoting entrepreneurship and the digital economy, such as the startup law, encouraged innovation by providing tax breaks and easing registration procedures for startups. 2018 Law No. 23 of 2018 was issued regarding supporting incentives for science, technology and innovation, which works to support technology and innovation and motivate those working in them, and recognizing the right of higher education and scientific research bodies to establish companies to exploit the outputs of scientific research, and that these bodies are exempt from paying taxes and customs fees as well as value-added tax on tools,

energy.	devices and materials necessary for research that they import from abroad. Revisions to investment laws, particularly the introduction of Investment Law No. 72 of 2017, simplified regulations for foreign investors, which fostered innovation in sectors such as renewable energy and ICT.
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Source: Authors

4.2. The Sub-Hypotheses verification

Five indicators were chosen that reflect the different stages of innovation to which of the selected sub-indicators had the most significant impact on economic growth in the period from 2011-2020, namely the spending on research and development as a percentage of GDP annually, Number of Scholarly Output, the market sophistication value from global innovation index (GII) which include the credit, investment, trade, competition, & market scale annually, the number of patent applications submitted by residents annually and the percentage of high-tech exports from total exports annually (Figure 4). Referring to the definition of economic growth as measured by the growth rate in the GDP annually (Investopedia, 2024), which refers to the outcome of all activities, services and products produced by the state in a specific period, which is one year, and based on the fact that innovation and technology are one of the determinants of economic growth and that it is also one of the four main pillars of the knowledge economy, and based on the fact that innovation and technology are one of the factors of production, the growth rate index in the per capita share of GDP annually was relied upon, as it is the true measure of the real welfare of the population because it represents the amount of actual goods and services that the individual obtains.

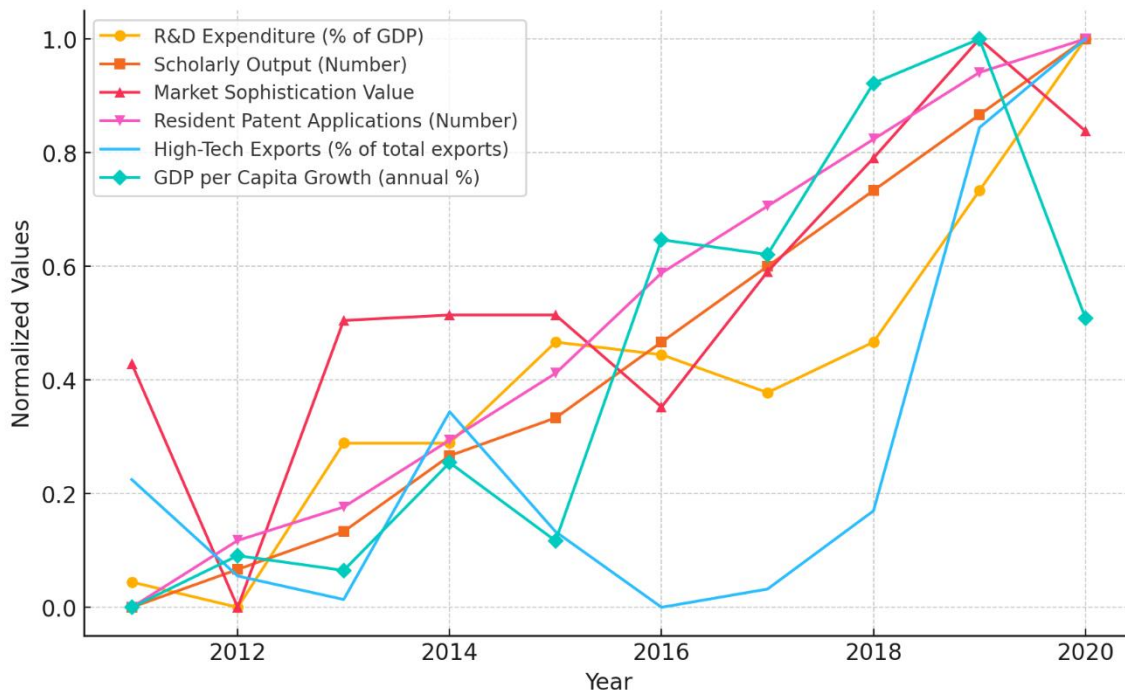


Fig. 4. Progression of sub-Innovation and Economic Growth Indicators

Source: WIPO, 2024; World Bank Open Data, 2024

To test the sub-hypotheses, the research utilized various statistical tests to analyze and identify which sub-indicators of innovation had the greatest impact on the annual growth rate of per capita GDP during the study period. First, the Jarque-Bera test was employed to determine whether the variables followed a normal distribution. Following this, a correlation matrix was used to examine the relationships between the variables. The Autoregressive Distributed Lag (ARDL) model was then applied to assess the dynamics within the data. Lastly, both short-term and long-term relationships between the model's variables were tested to refine the analysis further. The Jarque-Bera Normality test aims to examine the normal distribution of each variable individually, to determine whether the variable follows a normal distribution or not. Table 2 shows the descriptive analysis of the study variables from 2011 to 2020. The results indicate that the mean value of the "annual growth rate of per capita GDP (%)" was 1.467, closely aligning with the median value of 1.815, reflecting normality in the data. The skewness coefficient was 0.011, close to zero, and the kurtosis was 1.69, both within the acceptable range of ± 3 , indicating no issues with data normality. The Jarque-Bera normality test confirmed this, with a p-value of 0.700, greater than the 5% significance level. Similarly, the "percentage of R&D expenditure as % of GDP" had a mean of 0.695, equal to the median, with a skewness coefficient of 0.518 and a kurtosis value of 2.83, within the normal limits. The normality test for this variable returned a p-value of 0.795, confirming the data follows a normal distribution (1 of 2.85), indicating normality, supported by a normality test p-value of 0.850.

The "number of patent applications by residents" had a mean of 835.90 and a median of 836.00, with skewness of -0.053 and a kurtosis of 1.26, confirming normality through a p-value of 0.532. Finally, the "percentage of high-tech exports as a % of total manufactured exports" had a mean of 1.11, slightly higher than the median of 0.830, with a skewness coefficient of 1.236 and a kurtosis of 2.96. The p-value of 0.279 from the normality test indicates no significant deviation from normality.

Table 2. Descriptive analysis of sub-innovation indicators during 2011-2020

Indicators	GDP per capita growth (annual %)	R&D expenditure % of GDP	Number of Scholarly Output	Market Sophistication Value	Number of resident patent applications	High-tech exports as % of total manufactured exports
Indicators Symbole	Y1	X1	X2	X3	X4	X5
Mean	1.4670	0.6950	19486.00	36.260	835.90	1.1140
Median	1.815000	0.6950	18575.5	35.850	836.00	0.8300
Maximum	3.4900	0.9600	32,893.00	41.000	1027.00	2.6800
Minimum	-0.36	0.5100	11,426.00	30.500	618.00	0.5000
Std. Deviation	1.372241	0.133521	6,471.971	2.952287	168.4178	0.775445
Skewness	0.011708	0.518254	0.966	-0.234688	-0.053139	1.236561
Kurtosis	1.692362	2.837663	0.739	2.850024	1.262932	2.968452
Jarque-Bera	0.712694	0.458626	1.531850	0.101169	1.261958	2.548886
p-value	0.700230	0.795080	0.464904	0.950673	0.532071	0.279587

Source: Authors

Correlation Matrix (Pearson Correlation Matrix) examines the relationships between variables, aiming to determine whether multicollinearity exists among the variables. In other words, it assesses whether there is a strong correlation between the independent variables, which might impact the accuracy and quality of the

econometric model. High multicollinearity between independent variables can distort the model's results and lead to unreliable conclusions. Therefore, this matrix helps in identifying such potential issues, ensuring the robustness of the analysis and the validity of the model's outputs.

Table 3 presents the Pearson correlation matrix between the annual growth rate of per capita GDP (%) and several independent variables for 2011-2020.

The results revealed a statistically significant relationship between the growth rate of per capita GDP (%) and the percentage of R&D expenditure (% of GDP) at a 95% confidence level. The correlation value was 0.665, indicating a strong positive correlation. Similarly, a statistically significant relationship was found with the Number of Scholarly Output at the same confidence level, with a correlation value of 0.662, also indicating a strong positive correlation.

Table 3. Correlation matrix between study variables

Variables	Y1	X1	X2	X3	X4	X5
GDP per capita growth (annual %)	11					
R&D expenditure % of GDP	0.665	1				
	0.036					
Number of Scholarly Output	0.662	0.943	1			
	0.037	0.000				
Market Sophistication Value	0.694	0.805	0.767	1		
	0.026	0.005	0.010			
Number of resident patent applications	0.853	0.714	0.797	0.674	1	
	0.002	0.020	0.006	0.033		
High-tech exports as a % of total manufactured exports	0.325	0.766	0.807	0.691	0.431	1
	0.359	0.010	0.005	0.027	0.214	

Source: Authors

Additionally, the results showed a statistically significant relationship with Market Sophistication Value, where the correlation coefficient was 0.694 at a 95% confidence level, and the p-value was 0.026, which is below the 5% significance level. Furthermore, when examining the relationship between the annual growth rate of per capita GDP (%) and the number of patent applications by residents, the results indicated a statistically significant relationship at a 99% confidence level, with a correlation value of 0.853, demonstrating a very strong positive correlation. The autocorrelation of residuals was examined using the **Durbin-Watson test**, which yielded a value of 3.233, indicating that there is no issue of serial autocorrelation between the residuals as the value falls within acceptable limits. Additionally, the **Breusch-Godfrey Serial Correlation LM test** was conducted to further assess the quality of the model. The test returned a p-value of 0.434, which is greater than the 5% significance level, leading to the acceptance of the null hypothesis that there is no serial autocorrelation between the residuals, this confirms the robustness of the model in terms of error independence.

The analysis of the autoregressive distributed lag (ARDL) model for the first sub-hypothesis demonstrates a statistically significant effect of research and development (R&D) expenditure as a percentage of GDP on per capita GDP growth. With an R-squared value of 0.984, the model explains 98.4% of the variance in per capita

GDP growth. This highlights the substantial influence of R&D expenditure on economic growth. The model is significant at a 95% confidence level (p-value = 0.040), while the Durbin-Watson statistic of 3.020 indicates no issues with autocorrelation. The Breusch-Godfrey Serial Correlation LM test (p-value = 0.543) further supports the absence of serial correlation, confirming the robustness of the model (Table 4). For the second sub-hypothesis, the results show that the number of published peer-reviewed scientific articles has a strong, statistically significant impact on per capita GDP growth. The model's R-squared value of 0.998 indicates that 99.8% of the changes in per capita GDP growth can be attributed to scientific publications. The significance level is very high, with a p-value of 0.004, and no autocorrelation issues are detected (Durbin-Watson statistic = 3.034). The Breusch-Godfrey test result (p-value = 0.065) confirms no serial correlation, reinforcing the importance of scientific research output as a driver of economic growth.

Table 4. Estimation Results of the Autoregressive Distributed Lag (ARDL) Model for Each Sub-Hypothesis

Variable	1st sub-hypothesis	2nd sub-hypothesis	3rd sub-hypothesis	4th sub-hypothesis	5th sub-hypothesis
Y1(-1)	-0.067	-1.01	-1.368	0.344	0.281
Y1(-2)	-1.754		-2.363	-1.861	-1.363
X1	-12.309				
X2		0			
X3			-0.247		
X4				0.008	
X5					-0.699
X1(-1)	-2.557				
X2(-1)		-0.001			
X2(-2)		-0.002			
X3(-1)			-0.506		
X4(-1)				0.01	
X5(-1)					-0.598
X5(-2)					-1.373
Constant (C)	4.774	11.746	17.689	-12.52	-0.73
R-squared	0.984	0.998	0.859	0.916	1
Adjusted R-squared	0.943	0.994	0.507	0.805	0.999
F-statistic	24.001	224.806	2.442	8.203	914.69
Prob(F-statistic)	0.04	0.004	0.316	0.058	0.025
Durbin-Watson Stat	3.02	3.034	2.331	1.782	2.1

Source: Authors

However, the third sub-hypothesis, which examines the effect of domestic market size and market development on per capita GDP growth, does not show statistical significance. The model's p-value of 0.316 exceeds the 5% threshold, indicating no significant relationship between domestic market factors and per capita GDP growth. The Durbin-Watson statistic of 2.331 falls within acceptable limits, confirming no autocorrelation, but the hypothesis that domestic market size and development significantly influence economic growth is rejected based on these results. The fourth and fifth sub-hypotheses show strong positive relationships between patent applications and high-technology exports, respectively, and per capita GDP growth. The fourth sub-hypothesis reveals that 91.6%

of the variation in GDP growth is explained by patent applications ($R\text{-squared} = 0.916$), with a $p\text{-value}$ of 0.058. Similarly, high-technology exports account for 99.9% of the changes in per capita GDP growth in the fifth sub-hypothesis ($R\text{-squared} = 0.999$, $p\text{-value} = 0.025$). Both models show no issues with autocorrelation, as indicated by Durbin-Watson statistics of 1.782 and 2.100, respectively. The findings underscore the critical role of innovation, patent activity, and technological exports in driving economic growth (Table 4).

Figure (5) illustrates the confidence intervals for per capita GDP growth (% annually) over the study period and analyzes the relationship with the proposed variables for each sub-hypothesis. For the first sub-hypothesis, the Theil inequality coefficient is 0.033, which is less than 0.10, indicating that this model can be reliably used to predict future values of per capita GDP growth (% annually). For the second sub-hypothesis, the Theil inequality coefficient is 0.011, which is significantly below 0.10. This suggests that the model has high predictive accuracy and can be confidently used to forecast future values of per capita GDP growth. In the case of the fourth sub-hypothesis, the Theil inequality coefficient is 0.074, also below 0.10, meaning that the model can be relied upon to predict future values of per capita GDP growth. However, the accuracy is slightly lower compared to the first and second sub-hypotheses. As for the fifth sub-hypothesis, the Theil inequality coefficient is 0.003, which is far below 0.10. This reflects very high accuracy in predicting future values of per capita GDP growth, indicating that the model is exceptionally reliable for forecasting under this sub-hypothesis.

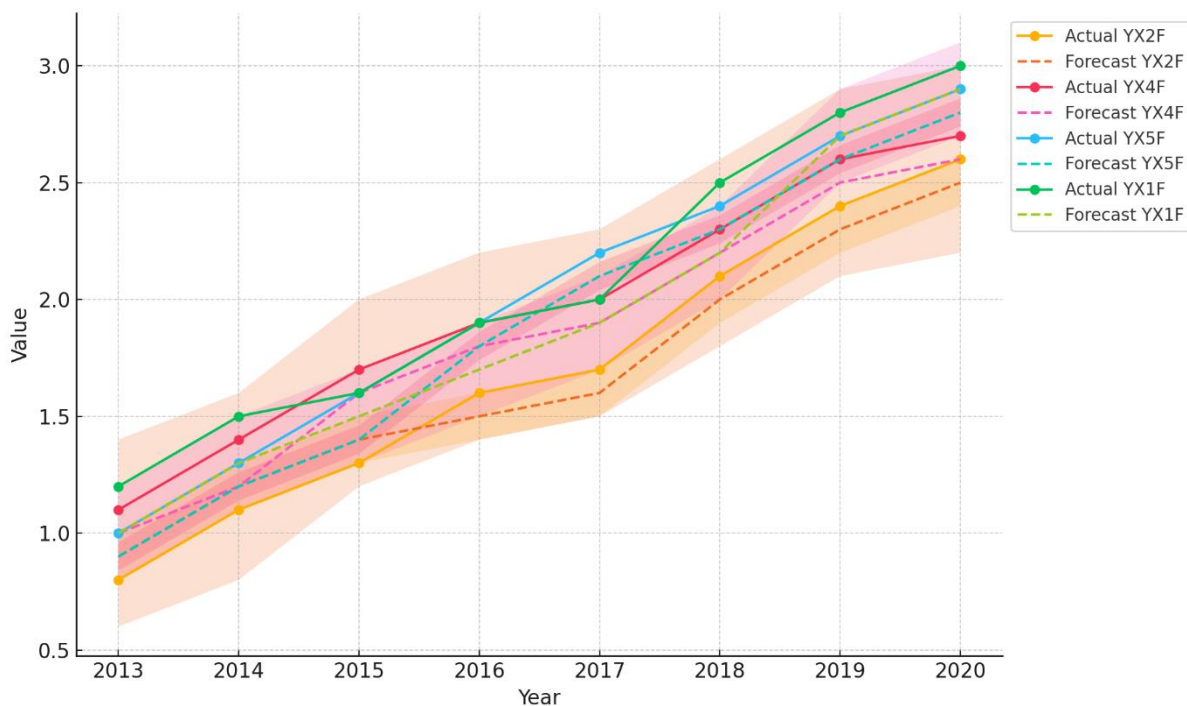


Fig. 5. Forecast vs Actual for Multiple Variables with ± 2 S.E.

Source: Authors

Thus, the hypothesis suggesting a statistically significant effect of R&D expenditure as a percentage of GDP on per capita GDP growth (% annually) can be accepted. Similarly, the hypothesis that the number of peer-reviewed published scientific articles has a statistically significant effect on per capita GDP growth (% annually) is also accepted. Additionally, the hypothesis proposing a statistically significant impact of resident patent applications on per capita GDP growth is accepted, as well as the hypothesis that the percentage of high-technology exports

out of total manufactured exports has a statistically significant effect on per capita GDP growth. However, the hypothesis suggesting a statistically significant effect of domestic market size and market development on per capita GDP growth is rejected.

4.3. Field Study Analysis

To identify the most influential and important indicators of innovation, the results of the field study showed that the scientific publishing index ranked first in importance, with 86.59%. In second place was the research and development expenditure index, which scored 82.12%. This was followed by the market competitiveness and development index, with a score of 69.89%. The least important indicator was the intellectual property and patent index, which came in at 59.56% Table 5.

Table 5. Relative importance of innovation indicators

Sub-indictors of Innovation	Standard deviation	Trend	Degree of importance
R&D Spending Index	0.668	Agree	82.12
Intellectual Property and Patents Index	1.016	Neutral	59.56
Technological Exports as a Share of Total Manufactured Exports Index	1.026	Neutral	65.38
Scientific Publication Index	0.680	Strongly Agree	86.59
Market Competition and Development Index	0.815	Agree	69.89

Effect of Events and Crisis on Innovation during 2011 to 2022

Participants were given a selection of political, economic, social, technological, and environmental factors and events to assess the degree of their influence on innovation (see Table 6 & 7). The survey results indicate varying levels of agreement across political, economic, and social events and factors. For political factors, the majority of the study sample (61.5%) expressed agreement, with 18.7% remaining neutral and 19.8% disagreeing. The mean score of 3.511, above the neutral midpoint, along with a standard deviation of 1.072, suggests a general tendency toward agreement with some diversity in opinion.

Similarly, responses to economic factors show 56.0% agreement, 24.2% neutrality, and 19.8% disagreement, resulting in a mean score of 3.412 and a lower standard deviation of 0.968, indicating a more consistent view of economic issues, though with a higher degree of neutrality compared to political factors. In contrast, responses toward social events and factors were more divided, with 41.8% agreeing, 31.9% remaining neutral, and 26.3% disagreeing. The mean score of 3.242, closer to neutral, and a relatively higher standard deviation of 1.250 reflect a more balanced distribution of opinions. This suggests that respondents were less decisive regarding social factors, leading to greater variability in responses, likely due to the subjective nature of social issues. Overall, the results highlight stronger consensus on political and economic factors, with more varied opinions on social issues.

Table 6. Effect of political, economic and social events and crisis on innovation from 2011 to 2022

Survey statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Standard deviation	Trend
Innovation activity in Egypt was negatively affected by the January 2011 revolution and the political instability from 2011-2014	11.0	8.8	30.8	22.0	27.5	1.285	Agree
Major development projects and infrastructure improvement projects initiated by the government in 2015 boosted innovation in Egypt	6.6	8.8	31.9	27.5	25.3	1.157	Agree
Political events and crisis						1.072	Agree
Innovation activity was delayed due to the state of collapse and economic instability in Egypt between the 2011 revolution and late 2014	8.8	12.1	27.5	28.6	23.1	1.223	Agree
Economic reform programs and addressing structural imbalances in the economy starting in 2015 contributed to enhancing innovation in Egypt	5.5	6.6	46.2	28.6	13.2	0.985	Neutral
Innovation activity in Egypt was affected after the decision to liberalize the exchange rate and float the Egyptian pound in late 2016	2.2	11.0	29.7	35.2	22.0	1.017	Agree
Innovation in Egypt was affected by Egypt's agreement with the International Monetary Fund in 2016, and Egypt's adoption of austerity policies on all economic axes	6.6	9.9	36.3	29.7	17.6	1.096	Agree
The decision to raise the value of the value-added tax on goods and services from 10-14% in 2016 contributed to the impact on innovation activity in Egypt	3.3	8.8	39.6	31.9	16.5	0.982	Agree
Economic events and crisis						0.968	Agree
Innovation activity in Egypt has declined due to the increase in unemployment and the lack of security stability after the events of January 2011.	11.0	15.4	31.9	22.0	19.8	1.250	Neutral
Social events and crisis						1.250	Neutral

Source: Authors

For Technological events and factors (Table 7), The results demonstrated a strong tendency towards agreement with technological events and factors, with 82.4% of respondents expressing strong agreement. Only 12.1% remained neutral, and a small portion, 5.5%, disagreed. The mean score for the responses was 3.973, with a relatively low standard deviation of 0.754, indicating a strong consensus and limited variability in responses toward technological factors. Similarly, 78.0% of respondents showed agreement for environmental events and factors, 17.6% were neutral, and only 4.4% disagreed. The mean score was 3.984, with a standard deviation of 0.831, indicating a general tendency towards agreement, though with slightly more variability compared to the technological factors.

In contrast, the responses regarding legislative events and factors reflected a more neutral stance from the study sample. The data show that 52.7% of respondents agreed, 31.9% were neutral, and 15.4% disagreed. The mean score was 3.374, with a standard deviation of 0.909, indicating a more balanced distribution of opinions. While the majority still leaned toward agreement, the higher percentage of neutral and disagreeing responses suggests greater uncertainty or mixed perceptions regarding legislative factors compared to technological and environmental factors, where consensus was much stronger.

Table 7. Effect of technological, environmental, legislative events and crisis on innovation from 2011 to 2022

Survey statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Standard deviation	Trend
The spread of smartphone use, the dominance of social media, and the ease of electronic communication enhanced the culture of innovation and entrepreneurship during the January 2011 revolution.	5.5	8.8	25.3	37.4	23.1	1.101	Agree
Reliance on technology, the spread of electronic platforms, and the trend towards digital transformation contributed to enhancing the culture of innovation during the Corona crisis of 2020 and beyond.	0.0	2.2	11.0	40.7	46.2	0.756	Strongly Agree
Technological events and crisis						0.754	Agree
The outbreak of the Corona pandemic and the complete lockdown in Egypt in 2020 led to a decline in innovation activities in Egypt	15.4	30.8	28.6	15.4	9.9	1.191	Neutral
Innovation activities in the health sector have increased and diversified since the outbreak of the Corona pandemic 2020	4.4	3.3	20.9	38.5	33.0	1.035	Agree
Supply chains were disrupted as a result of the outbreak of the Corona pandemic	3.3	2.2	19.8	36.3	38.5	0.988	Agree
Environmental events and crisis						0.831	Agree
The current legislative environment (Innovation Incentives Law and Small Enterprise Development Agency Law) has supported and enhanced the performance of innovative activity in Egypt.	8.8	11.0	45.1	26.4	8.8	1.032	Neutral
The government's exemption of imported tools, equipment and materials needed for research and development from taxes, customs duties and value-added tax has enhanced innovative activity in Egypt.	3.3	5.5	37.4	36.3	17.6	0.954	Agree
Legislative events and crisis						0.909	Neutral

Source: Authors

Effect of innovation on economic growth from 2011 to 2022

The results from Table (8) indicate that the study sample leaned towards agreement on the topic of economic growth, with 49.5% of respondents expressing agreement, 41.7% remaining neutral, and 8.8% disagreeing. The overall mean response was 3.484, with a standard deviation of 0.721, suggesting a slight tendency towards agreement but with a substantial proportion of neutral responses indicating a level of uncertainty or mixed opinions regarding economic growth. Regarding specific statements related to economic growth, the statement "Startups provide at least three job opportunities per company, contributing to increased income" ranked first in terms of agreement, with 74.7% of respondents agreeing and a weighted mean of 3.989. The second most agreed-upon statement was "Innovation-based companies generate higher profits than their counterparts," with 72.5% agreement and a weighted mean of 4.000. The third statement, "The current innovation system focuses on supporting products with a high percentage of local components," saw 56.0% agreement. Lastly, the statement

“The current innovation system offers more opportunities to attract technological or innovative companies for internal and external investments compared to others” received the lowest level of agreement, with 35.2% agreeing and a weighted mean of 3.198, indicating a relatively lower perception of this aspect of the innovation system.

Table 8. Effect of innovation on economic growth axis

Survey statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Standard deviation	Trend
The current innovation system focuses on introducing new methods and approaches to the production process to reduce its costs and enhance the competitiveness of the product because it works on the optimal use of resources	4.4	13.2	34.1	29.7	18.7	1.078	Agree
Innovation-based companies achieve greater profits than their counterparts	1.1	2.2	24.2	40.7	31.9	0.869	Agree
The current innovation system enhances the opening of new internal and external markets, which supports growth	4.4	15.4	31.9	28.6	19.8	1.108	Agree
The current innovation system in Egypt increases the per capita income rate due to increased productivity and its diversity, economic mobility and development in the markets	4.4	19.8	38.5	25.3	12.1	1.038	Neutral
Start-ups provide at least 3 job opportunities in each company, which contributes to increasing income	0.0	4.4	20.9	46.2	28.6	0.823	Agree
The current innovation system provides opportunities to attract technological or innovative companies to internal and external investments more than their counterparts	4.4	20.9	39.6	20.9	14.3	1.067	Neutral
The current innovation system focuses on supporting products with a high percentage of local components	4.4	11.0	28.6	48.4	7.7	0.945	Agree
The current innovation system contributes to raising the percentage of Egypt's exports of high-tech products as a percentage of the total manufactured products, which is reflected in the gross domestic product	11.0	14.3	38.5	22.0	14.3	1.170	Neutral
Economic growth						0.721	Agree

Source: Authors

The impact of innovation indicators on economic growth during Events and Crises

The analysis shows statistically significant direct effects of several key indicators on economic growth (Figure 6), each at a 99% confidence level. First, R&D expenditure has a positive and significant impact on economic growth, with a path coefficient of 0.333, meaning that for every unit increase in R&D spending, economic growth rises by 0.333 units. This indicator explains 40% of the variation in economic growth. Similarly, intellectual property and the number of patents have a direct effect, with a coefficient of 0.313, contributing to a 42% explanation of changes in economic growth. An increase in patents and intellectual property leads to notable improvements in economic outcomes.

Moreover, technological exports show the strongest direct effect, with a coefficient of 0.576, meaning that a one-unit increase in the proportion of technological exports boosts economic growth by 0.576 units, explaining 52.2% of the growth variation. Scientific publications also contribute significantly to growth, with a coefficient of 0.213, accounting for 35.7% of the changes. Lastly, market competitiveness and development positively influence economic growth, with a coefficient of 0.293, explaining 37.1% of the variation. These results underscore the critical roles of R&D, innovation, technological exports, knowledge production, and market sophistication in driving economic growth.

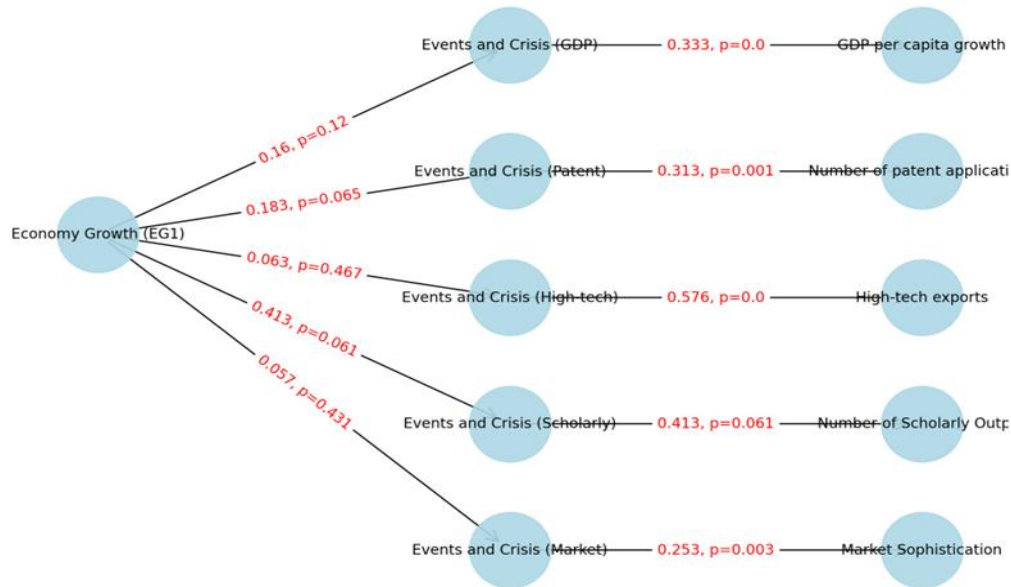


Fig. 6. Relation between Sub-indicators of innovation and economy growth

Source: Authors

By analysis of the effect of events and crisis, the analysis shows no statistically significant impact of events and crises on the relationship between R&D expenditure and economic growth, with a path significance of 0.120, which exceeds the 5% error threshold. Similarly, no significant indirect effects were found for technological exports or market competitiveness on economic growth through events and crises, with path significance levels of 0.462 and 0.431, respectively, both higher than the 5% threshold. Additionally, the results show no significant effect of crises on the relationship between scientific publications and economic growth, with a path significance of 0.395. In contrast, the findings confirm a statistically significant indirect effect of intellectual property and the number of patents on economic growth through events and crises, with a path coefficient of 0.189 at a 99% confidence level. This indicates that crises play a moderating role in the relationship between intellectual property and economic growth, albeit to a lesser extent than the direct effects of intellectual property on economic development.

Conclusion

This study highlights the crucial role that innovation plays in driving economic growth in Egypt, as demonstrated by the theoretical and applied analysis of the "Intilaq" program under the Academy of Scientific Research and Technology. The results show a statistically significant and positive relationship between these indicators and the annual growth in per capita GDP by examining various innovation-related indicators, such as research and development (R&D) expenditure, patent filings, and high-tech exports. The most influential variables on economic growth were high-tech exports and peer-reviewed scientific publications, followed by R&D expenditure, the number of patent applications, and the number of registered startups. However, the study found

that the development of local markets had no statistically significant impact on economic growth during the study period, which can be attributed to the political and economic challenges Egypt faced during this time. Despite these challenges, the data suggests that innovation-related activities continued to positively influence economic performance. The findings also suggest that innovation is a key driver of knowledge-based economic development, although some areas, such as the development of local markets, require further attention.

Moreover, the field study revealed a gap in the effectiveness of government support programs for innovators. Participants expressed reservations about the efficiency of innovation support programs and the legislative framework, indicating a need for improved economic and fiscal policies to support the innovation ecosystem better. To sustain the positive impact of innovation on economic growth, it is essential for the government to enhance policies, especially in intellectual property protection and support for high-tech exports, to ensure the continued contribution of innovation to Egypt's economic growth, despite the challenges and crises faced during the study period.

Recommendation

To enhance the creative scene in Egypt, several strategic actions are necessary to address existing gaps and build a sustainable ecosystem. The following recommendations aim to enhance collaboration, streamline processes, and support innovators and entrepreneurs.

- **Develop Industry-Focused Innovation Initiatives:** Prioritize identifying industrial challenges and national needs and launch targeted initiatives for innovators to address these issues. This will help create practical solutions that boost national income and improve citizens' quality of life.
- **Establish a National Innovation Authority:** Create a central authority to coordinate between different ministries and sectors, focusing on strategic planning, linking efforts, and addressing gaps in the innovation ecosystem. This body should serve as a facilitator rather than an executor.
- **Create a Clear National Innovation Policy:** Implement a well-defined, comprehensive national policy on innovation. This policy should outline clear objectives and be binding on all relevant stakeholders to foster a supportive environment for innovators and entrepreneurs.
- **Enhance Government-Private Sector Partnerships:** Encourage partnerships between the government, private sector, and civil society organizations to provide joint financial and technical support to innovators through grants and sponsorship programs.
- **Improve Innovation Legislation:** Review and update laws and regulations related to innovation to provide better incentives, streamline processes, and offer support packages that facilitate the growth of innovative projects.
- **Support Young Innovators:** Allocate dedicated programs and grants for young innovators aged 20-40 to encourage innovation within this demographic and provide them with the necessary resources for success.
- **Promote Intellectual Property Awareness:** Launch awareness campaigns to educate the public on the importance of intellectual property protection and patent registration. These efforts should target all segments of society, not just those with higher education levels, to broaden understanding of intellectual property rights.

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