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Review

Innovation Ecosystems in Hydrocarbon-Based Economies: Opportunities and Challenges

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Abstract: Innovation is rapidly growing and affecting various industries, including hydrocarbon processing. This study aims to conduct a comprehensive and organized review of the literature on innovation ecosystems and their performance within hydrocarbon-based economies. It will examine existing definitions of innovation ecosystems and related concepts and conduct an in-depth analysis of certain hydrocarbon-based economies and their Global Innovation Index (GII) development from 2011 to 2022. The term "innovation ecosystem" has gained considerable attention from scholars and practitioners over the past fifteen years. Despite the proliferation of research in this area, there are concerns about its fragmented knowledge base. While previous reviews have highlighted the theoretical connections between innovation ecosystems and related concepts, there is still a need for a more comprehensive understanding of the current state of innovation ecosystem research. This study used a systematic literature review approach that combines bibliographic coupling and content analysis methods, drawing on over 40 studies to identify five streams of current innovation ecosystem research: Technology innovation, platform innovation ecosystems, regional development, innovation ecosystem conceptualization and theorization, and entrepreneurship and innovation. This study's contribution lies in highlighting the specific elements that contribute to the development of an innovative economy based on hydrocarbons.

Keywords: innovation ecosystem; technology innovation; entrepreneurship; hydrocarbon-based economies; innovation systems

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1. Introduction

One of the greatest challenges is the huge decrease in hydrocarbon prices over the last five decades. This condition has adversely impacted the hydrocarbon exports of countries and has had various impacts on the country's budget, and caused stress on income, urban development, and forging trade balance [1]. As per Mishrif [2], the past decade has seen a significant drop in hydrocarbon prices; prices were around USD 100 per barrel between 2010 and 2014, and then dropped by 70% in 2016 to about USD 30 per barrel. These variations have raised grave concerns about the sustainability of the hydrocarbon economies. It was seen as a warning to these countries to build a solid diversified economy; accordingly, such an economy can withstand changes and drops in hydrocarbon prices. Additionally, Ustaoğlu and İncekara [3] highlighted that, in light of recent events in the dramatic drop in hydrocarbon prices, it is becoming extremely difficult to ignore the importance of economic diversification.

As stated by Mishrif [2], "The fragility of the national economic cycle is evident in the negative impact of oil price fluctuations on export revenues and government income, as well as the import of goods, services, and workers to meet domestic needs. Such impact affects growth levels in Gross Domestic Product (GDP) negatively". Evidence suggests

that economic sustainability is among the most important factors for a nation's success; therefore, this would necessitate a comprehensive approach to the long-term utilization of hydrocarbon revenues in a sustainable manner [4]. It is now well established from various studies that vulnerability is the "Degree to which a system is unable to cope with the selected adverse event" [5]. Similarly, hydrocarbon-based economies are highly vulnerable to hydrocarbon price drops.

Innovation is growing at a very fast rate, and it is transforming different sectors of the economy globally. Applying digital technologies in manufacturing, education, and business models leads to better growth opportunities and high-value revenue. Innovation and technology have been central to industrial development for decades, transforming most hydrocarbon-based economies from resource-dependent to knowledge-dependent countries [6]. An innovative economy based on hydrocarbons leverages the unique specifics of this sector for resource optimization to maximize the extraction efficiency of hydrocarbon resources while minimizing environmental impact. In addition, other specifics include diversification of extraction and production activities to enhance resilience and long-term sustainability, fostering collaboration and partnerships for knowledge exchange and technological advancements, environmental stewardship, and supporting entrepreneurship.

Innovation is impacting almost every aspect of human life. Digital transformation is helping professionals and businesses develop new solutions and modify existing experiences, processes, and cultures to meet the ever-evolving market and human needs. The reimagining of businesses in the digital era has impacted many countries, including hydrocarbon economies that have traditionally relied on natural resources to run their countries. Notable countries in this category include Norway, Brazil, and the United Arab Emirates (UAE). Most hydrocarbon-based countries are shifting from resource dependency to knowledge dependency. Leading economies like Germany, the USA, the UK, China, and Singapore have invested a lot in knowledge, which is why they are highly developed [7]. The 2020 International Monetary Fund (IMF) Report [8] indicated that the main factor behind the economic differences among countries that are said to be wealthy, developing, or underdeveloped is the extent to which the respective nations have developed and utilized their knowledge domain [6]. Several countries in the Arabian Gulf, Latin America, and parts of Africa are endowed with natural resources. Yet, over 50% of expertise is imported from economic giants like China, France, and the USA [9]. As a result, most countries realize the importance of powering their economies through developing knowledge and not necessarily depending on natural resources.

In 2020, the World Bank reported that a knowledge-powered economy is mainly defined by progressive learning, reliability, networking, and agility. The subject of knowledge-based development surpasses the usual learning, and is supposed to encompass the infusion and utilization of learned knowledge in every part of the economy [10]. A modeled approach was applied in creating and developing a knowledge-based economic structure appropriate to Qatar's scenario. The starting point towards attaining an effective knowledge-based economy was to change the approaches and perceptions of the leaders, society, and business to a knowledge-oriented standpoint [7]. The government significantly transitioned to a knowledge-driven economy by winning national and global trust and creating innovative ecosystems with effective learning and digital infrastructure. The leadership also created business settings where local and foreign organizations could compete and thrive.

Qatar is among the most promising and competitive economies in the Middle East, aiming to be a global leader in relying on knowledge to drive economic diversification [10]. Qatar has developed a benchmarking scoreboard, similar to Saudi Arabia, Malaysia, and Thailand, to promote the transition toward a knowledge-based economy [7]. Further discussion of Qatar's best practices in its move from a resource-driven economy to a knowledge-driven economy will be conducted in the following sections.

This study aims to conduct a comprehensive and systematic literature review on innovation ecosystems and performance within hydrocarbon-based economies, review

received definitions of innovation ecosystems and related concepts, and conduct an in-depth analysis of certain hydrocarbon-based economies and their Global Innovation Index (GII) development from 2011 to 2022. The rest of the paper is organized as follows: First, we discuss the fundamental basis of innovation ecosystems. We include definitions and characteristics of innovation ecosystems. Second, the dynamics of innovation ecosystem development and management are studied. Third, innovation strategies and policies in hydrocarbon-based economies are included. Fourth, the GII progression for selected countries is discussed. Fifth, we present the conclusion and recommendations.

2. Methodology

Although numerous studies have been conducted on the innovation ecosystem, there are concerns regarding the fragmented nature of its knowledge base. While previous reviews have emphasized the theoretical associations between innovation ecosystems and related ideas, there is still a requirement for a more thorough comprehension of the present state of research in this field. Therefore, this study employed a systematic literature review approach that integrated bibliographic coupling and content analysis techniques. By examining 40 studies, the research identified five main areas of current innovation ecosystem research: technology innovation, platform innovation ecosystems, regional development, conceptualization and theorization of innovation ecosystems, and entrepreneurship and innovation. The literature from the Scopus database was reviewed using filtering techniques and specific keywords for the period between 2008 and 2022. A systematic review was conducted to perform a comprehensive search of the literature and determine the total number of articles that specifically addressed the innovation ecosystem, with a particular emphasis on the hydrocarbon-based industrial sector. The keywords: innovation, innovation ecosystem, and innovation ecosystem and entrepreneurship were used to search articles that were published. The search resulted in the acquisition of over 10,000 documents, encompassing various types of literature such as journal articles, books, conference papers, and letters. Forty studies were used to explore the innovation ecosystem in hydrocarbon-based economies, with a particular focus on identifying opportunities and challenges. The forthcoming sections of this study contain a significant contribution from the performed comprehensive review.

3. The Fundamental Basis of Innovation Ecosystems

Innovation ecosystems refer to dynamic and interconnected networks of individuals, entities, and resources that foster the development and diffusion of innovative ideas, methods, products, technologies, and solutions. Xu and Maas [11] explained that the idea of innovation ecosystems builds upon Freeman's [12] notion of national innovation systems and Lundvall's [13] concept of innovation systems. Scholars who follow the evolutionary approach in economics have expanded upon these original works to investigate innovation systems at different levels, from local to regional to national. Various academic perspectives have adopted the concept of innovation ecosystems because of its flexibility, resulting in a wide range of definitions with diverse theoretical and empirical emphases. For instance, Granstrand and Holgersson [14] defined innovation ecosystems as "the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors". With emphasis on the collective generation of outputs, Adner [15] defined innovation ecosystems as "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize". Other innovation scholars put an emphasis on the economic geography, defining innovation eco-systems as "institutional, geo-graphic, economic, or industrial contexts [which] can be analyzed at different levels of aggregation (e.g., firms, industries, universities, regions, and nations)" [16]. Some innovation scholars have focused on knowledge and learning dimensions and define innovation ecosystem as "clusters (physical or virtual) of innovation

activities around specific themes (e.g., bio-technology, electronics, pharmaceutical and software)" [17].

Several conceptualizations of innovation-related systems have been proposed, such as national, regional, sectoral, and corporate innovation systems, defined as follows:

Innovation system: All important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations [18].

National Innovation System: According to Freeman's [12] concept of the National Innovation System, all aspects of the economic structure and institutional setup that impact learning and exploration, including the production, marketing, and finance systems, form subsystems where learning occurs.

Regional Innovation System: This refers to the institutional infrastructure that supports innovation within the production structure of a region [19].

Sectoral Innovation System: Involves a group of firms that develop and manufacture products and generate and use technologies in a specific sector. These firms are interconnected through cooperative and competitive processes in innovation and market activities [20].

Corporate Innovation System: Includes all actors, activities, resources, and institutions relevant to the innovative performance of a corporation or group of collaborating companies, such as universities, institutes, and agencies [21].

Several key elements characterize innovation ecosystems. An innovation ecosystem's main characteristic is its stakeholders' diversity and heterogeneity. This includes companies, universities, institutions, government agencies, and individuals who collaborate in various roles to drive innovation [22]. This diversity allows for varied perspectives, resources, and expertise to develop new technologies and breakthroughs. Additionally, diversity exceeds the various stakeholders. It embodies other aspects, such as the diverse and dynamic customer requirements, multi-stage co-innovation process, and multi-platforms [23]. Another important characteristic is access to funding and decentralization resources, such as technologies, mentorships, and networking opportunities. These resources play a major role in developing new ideas for the market. The third distinguishing characteristic is a skilled and educated workforce equipped to work in a rapidly changing and technology-driven economy to facilitate a system-level output [22]. The fourth distinguishing characteristic is a culture that values and encourages risk-taking, experimentation, and learning from failure. This occurs with supportive policy and government regulations that create an environment conducive to innovation. The fourth distinguishing characteristic is the nature of the ecosystem governance challenge, as interactions and collaboration among ecosystem stakeholders enable them to specialize in specific roles not necessarily defined by formal contracts [22].

Innovation ecosystems should be seen as the natural environment of such collaborative networks tailored to co-create values. Co-creation of value is an active, creative, and social process based on collaboration between producers and users, which the firm initiates to generate value for customers and compete to pass others in the category. Producers build competitive benefits by learning for their organizations, while users benefit from greater personalization and value [24]. Complex factors influence the creation, development, and diffusion of innovative ideas, products, and services in dynamic ways. Key elements include entrepreneurship and new ventures, talent and human capital, research and development (R&D) activities, access to funding and financing, networking and collaboration, legal and regulatory frameworks, infrastructure and technological capabilities, market demand, and consumer preferences. These elements interact and influence each other in dynamic ways, leading to the emergence of new technologies, products, and businesses and the development of existing ones.

4. Innovation Strategies and Policies in Hydrocarbon-Based Economies

Knowledge-based advancement remains the foundation of modern economies. States and cities cannot continue to build their economy without access to the fountains of innovation and knowledge [25]. Hydrocarbon-based economies take advantage of the unique characteristics of the hydrocarbon sector to drive economic development, technological innovations, and environmental sustainability. Key aspects of hydrocarbon-based economies are: (1) Efficient resource utilization, (2) capturing new growth opportunities for economic diversification beyond traditional hydrocarbon activities, (3) collaborations between industry, academia, and government institutions enable the sharing of expertise, resources, and funding, facilitating the innovative solutions and fostering innovation ecosystems, (4) integration of technologies, such as automation, data analytics, Internet of Things (IoT), artificial intelligence (A.I.), and robotics to improve exploration techniques, optimize production processes, and enhance safety and operational efficiency, and (5) transformational entrepreneurship and skills development [11]. Innovation plays a key role in enhancing social development and economic growth. The Gulf Cooperation Countries (GCC) have adopted several innovative strategies to reduce the over-dependence on hydrocarbon revenue and move towards an innovation-based economy [26].

The UAE is one of the leading GCC nations in creating an innovative enabling environment. Particularly, the country has embarked on an initiative dubbed the National Innovation Strategy (NIS) [27]. The NIS primarily focuses on initiatives that foster innovations, including promoting R&D across universities and incentivizing entrepreneurship and innovation incubators to convert their ideas into viable projects [26]. The NIS has developed the Innovative Government initiative to equip and train government staff with the requisite skills for innovation. Such programs have made the UAE, particularly Dubai, the leading tourism and banking hub across the Gulf. This success can be attributed to the UAE's Science, Technology, and Innovation (STI) policy [27]. This policy facilitates innovations in numerous sectors, such as space sciences, urban and architecture design, petroleum geosciences, artificial intelligence, and robotics. As a result, the UAE is gradually becoming less reliant on hydrocarbon income.

Saudi Arabia is improving in some key areas of innovation, including industry–academic cooperation and the number of patents and research articles it generates. The King Abdulaziz City for Science and Technology (KACST) is the country's major government agency that champions innovation efforts [26]. KACST's Saudi Arabian Business Innovation Research initiative aims to help the growth of Saudi enterprises by supporting research. The BADIR initiative has also developed incubators with aspirations to have 80 incubators nationwide by 2025 [28]. The BADIR initiative has already yielded considerable benefits from its three strategies: (1) Ataalam is offering a women's online learning environment, (2) ACE Biotech is providing reagents and kits for buffers, and (3) RNA/DNA isolation, polymerase chain reaction, and cloning [28]. In particular, the Saudi Arabian government has developed innovation-centered policies, including entrepreneurship and start-up funds, research commercialization to nurture R&D, and direct investments in foreign ventures.

Qatar has shown notable commitment to transitioning into an innovation-based economy via its National Vision 2030 strategy. The country has invested a substantial amount of its national budget in enhancing education, entrepreneurship, innovation, and Information and Communication Technology (ICT). This move has led to the establishment of innovation-focused institutions, such as the Qatar Business Incubation Center (QBIC) and Qatar Science and Technology Park (QSTP) [29]. The Qatari government has created various policies to support these institutions, such as the urban development plan to promote urban center expansion and ICT procedures for its infrastructures, services, products, and e-government platforms [26]. In the same vein, Qatar has enhanced its ICT and innovation policies in preparation for the 2022 FIFA World Cup, as it is the host country for this international event [29]. This indicates that Qatar has made significant efforts to diversify its economy. Currently, Qatar is among the fastest-growing economies in the Gulf. The country is adopting innovation in most sectors, including energy, transport,

manufacturing, sports, and education. Qatar has demonstrated its resolve to attain a stable economic environment that effectively facilitates investments in the last three decades. Solid institutional frameworks focused on supporting economic growth utilizing intangible resources like knowledge, skills, and creativity have facilitated the great strides realized. The government has developed innovative policies and business registration and licensing processes and instituted frameworks, such as Qatar National Vision (QNV) 2030, that focus on supporting national development. Moreover, Qatar is becoming a leading technological and industrial hub. Today, Qatar's business ecosystem is open to creativity and innovation and receives significant government support.

Oman has embarked on promising strategies that will see the country minimize its reliance on hydrocarbon revenues. The country's NIS and its Vision 2040 have demonstrated a political will to join other hydrocarbon-based economies in moving towards an innovation-based economy [30]. The NIS focuses on the country's economic diversification efforts. The Research Council (TRC) is mandated to ensure the innovation strategy succeeds [31]. As a result, TRC has embarked on numerous initiatives to foster an innovation culture in Oman. For instance, the Individual Innovation Award is a program created by TRC to support different innovative projects within the country [31]. In addition, TRC has established the Oman Chamber of Commerce and Industry Innovation Award, which has since received a tremendous response and shaped an enabling setting for innovators [31]. Oman's NIS is founded on four key pillars: economic diversification, social and institutional integration, intellectual property and knowledge transfer, and human capital [30]. The Omani government insists that harmonizing innovation policies will facilitate a successful shift to a knowledge-based economy. These policies encompass key areas, including R&D, economic diversification, education, and infrastructure.

Kuwait and Bahrain are among the GCC countries aiming to shift to an innovation-based economy. Accordingly, the countries have developed national strategies for economic transformation strategies and procedures. These are Kuwait's Vision 2035 and Bahrain's Economic Vision 2030 [25]. However, as per Fagerberg et al. [32], these countries have shown that these long-term plans are yet to deliver tangible outcomes, and the main challenge in diversifying economies across these countries is the lack of measures of R&D investments and collaboration between universities and the corporate world.

Norway has one of the greatest per capita incomes globally. However, since 2014, economic growth has slowed, and unemployment has soared. In addition, low crude oil and gas prices have caused the energy industry to reduce petroleum investments, which has had a knock-on effect on other industries [32]. As a result, the Norwegian government had to devise a new strategic framework by boosting public R&D financing and solidifying efforts to enhance research quality and support the industry's diversification away from gas and oil. Particularly, Norway has been successful in achieving a knowledge-based economy due to capitalizing on innovation promotion agencies. These entities are responsible for coordinating cooperation between stakeholders.

The promotion agencies' major responsibility is identifying policies that can enhance the general environment, selling those policies to their stakeholders or owners, and developing connections among the most influential leaders. For instance, Innovation Norway coordinates all operations related to the country's national scientific, technological, and innovation paradigm [33]. Additionally, robust investor protection regulations remain a top priority for Norway. Such measures include disclosing transaction data, bankruptcy laws, and the directors' liability for damages caused.

5. Global Innovation Index Progression for Selected Countries

The GII highlights innovation drifts by country [34]. Essentially, GII identifies elements of the global economy that facilitate innovation. Such elements include Institutions, Infrastructure, Technology Outputs, Human Research and Capital, the Sophistication of Markets, and Business Advancement. This paper aims to comprehensively analyze selected hydrocarbon-based economies along with GCC nations from 2011 to 2022 in terms of the

GII, as depicted in Figure 1. The GII shows that Norway's average innovation value from 2011 to 2022 is 52.68 points, with a minimum of 48.8 points in 2022 and a maximum of 56.4 points in 2012. The latest value from 2022 is 48.8 points. Figure 1 supports the mentioned facts in the case of Norway from 2011 to 2022 (shown in Figure 1a). This decrease in the GII number in recent years in the case of Norway could be mainly due to having weak innovation indicators concerning R&D, IT exports, high-tech exports, and the resident's patent applications. Norway compares fairly in the global innovation ecosystem with the latest value from 2020 of 2.28%, because the global average expenditure on R&D based on research in 2020 from 67 countries was 1.3%. Norway's average value of innovation is manifested through exports of Information Technology products and services. The average value of this indicator held the lowest worth of 0.79% in 2012 and the highest rate of 1.97% in 2001. The latest value from 2020 is 1.39%. Norway's other innovation indicator within this period is the number of patent applications by residents. The average value of this indicator within the specified period was 1057 patent applications, with a minimum number of 693 applications recorded in 1982 and a maximum value of 1335 in 1999. The most current value was recorded in 2020 at 880 applications. Norway is faring well in the global innovation arena, because the global average of patent applications based on 117 countries is 19,040 [35].

Small state-driven countries such as Singapore, Ireland, and Finland compare fairly well with global giants such as Germany and USA in innovation. For instance, Singapore is ranked seventh by the GII in the top ten most innovative global economies. In 2022, Singapore ranked first in innovation inputs and fourteenth in innovation outputs. Its best-performing innovation metric is tertiary efficiency, which guarantees a gross enrollment of approximately 85% in higher education. In the case of Singapore, the average value with regard to GII during 2011–2022 was 59.08 points, with a minimum of 56.6 points in 2020 and a maximum of 63.5 points in 2012 (shown in Figure 1b). The latest value from 2022 is 57.3 points [36]. Such a fluctuating trend in the GII number in the case of Singapore can be due to having disrupted innovation capabilities, among others.

On the other hand, Finland's innovation performance is commendable as it ranks ninth in the global economy among the 48 high-income-group economies. The global average of this indicator based on 128 countries is 59.13 points, which makes Finland a fair global competitor (shown in Figure 1c) [37]. Such a positive trend in the GII number in Finland is due to better innovation inputs, and a high percentage of the country's GDP is spent on R&D. Canada ranks fifteenth in the global economy. The global average of this indicator based on 128 countries was 54.51 during 2011–2022, which makes Singapore and Finland global competitors (shown in Figure 1d) [38]. In the case of Ireland, during 2011–2022, the average value concerning GII stood at 55.76 points, with a minimum of 48.5 points in 2022 and a maximum of 59.1 points in 2015 (shown in Figure 1e). The latest value from 2022 is 48.5 points [39]. The prime reason for this increase in the GII number of Ireland could be ascertained as a better ranking in innovation outputs than inputs.

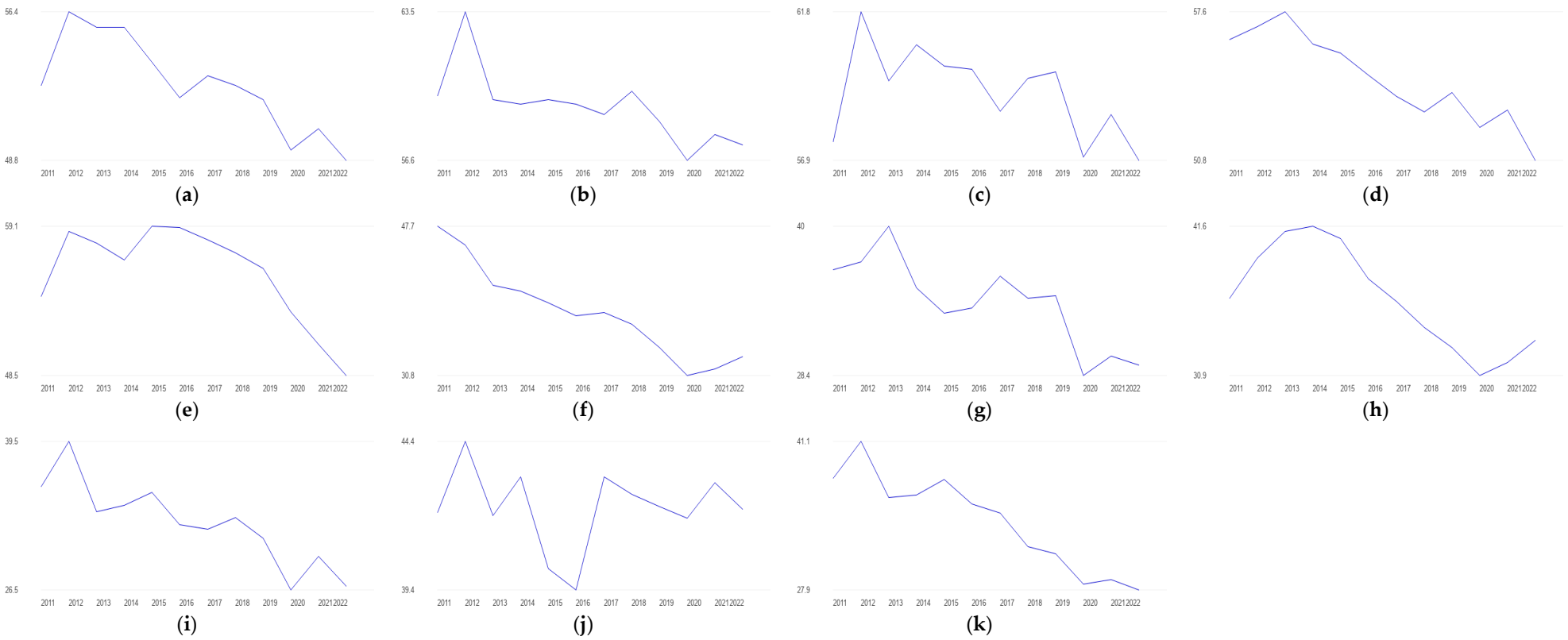

Figure 1. Global Innovation Index, 2011–2022 (**a**) Norway [35], (**b**) Singapore [36], (**c**) Finland [37], (**d**) Canada [38], (**e**) Ireland [39], (**f**) Qatar [40], (**g**) Kuwait [41], (**h**) Saudi Arabia [42], (**i**) Oman [43], (**j**) UAE [44], (**k**) Bahrain [45].

With regard to the GCC countries, it can be noticed that Qatar's GII progression seemed to be higher than that of Kuwait because the average value of the former stood at 37.88 points (maximum 47.7 points in 2011 and minimum 30.8 points in 2020) during 2011–2022 (shown in Figure 1f) [40]. Such an increase could be seen in Qatar's GII number case because of more impressive innovation inputs than outputs. Nevertheless, in contrast, the same indicator for Kuwait amounted to 34.03 points (a maximum of 40 points in 2013 and a minimum of 28.4 points in 2020) within a similar period (shown in Figure 1g) [41]. On the other hand, amongst Oman and Saudi Arabia, the GII progression of Saudi Arabia is greater than that of Oman, as its average value amounted to 36.38 points during 2011–2022 (shown in Figure 1h) [42]. The fluctuating trend in the GII number of Saudi Arabia can be due to exceptional innovation agendas that can lift the nation into a more developing one. However, this value in the case of Oman stood at 32.31 points within the same period (shown in Figure 1i) [43]. In the UAE, the average value concerning GII stood at 42.16 points during 2011–2022 (shown in Figure 1j) [44]. Such an increase in the GII number in recent times in the case of the UAE can be because it has made a significant level of investments in innovation drivers such as R&D. However, in contrast, a similar value with regard to Bahrain was identified as 33.93 points within the parallel fiscal period (shown in Figure 1k) [45].

6. Conclusions and Future Work

Innovation and technology have played a central role in industrial development, transforming most hydrocarbon-based economies from resource-dependent to knowledge-dependent countries. Norway has been successful in achieving a knowledge-based economy due to capitalizing on innovation promotion agencies. This paper is devoted to providing a comprehensive and in-depth study of the innovation ecosystems in hydrocarbon economies. More generally, this paper's main contribution is its focus on innovation strategies and policies in hydrocarbon-based economies and the GII progression for selected countries. The paper also highlights some success stories of countries that have diversified their economies and promoted innovation through targeted policies and investments. For example, Qatar is adopting innovation in most sectors, including energy, transport, manufacturing, sports, and education, via its National Vision 2030 strategy. This is evident by the fact that the country has invested substantially in enhancing education, research and development, entrepreneurship, innovation, and ICT, promoting digital transformation, and fostering collaboration between academia and industry. In addition, GCC countries have been working to promote innovation and diversify their economies away from hydrocarbons. As a result, the region has shown promising progress in recent years, as reflected in their GII rankings. However, extensive and comprehensive future research studies are required and highly recommended to explore and identify the relationship between the research output and the GII progression of certain hydrocarbon-based economies.

There are significant opportunities for innovative ecosystems based on hydrocarbons, including funding and resource optimization, technological integration, economic diversification, and collaboration and partnerships. Innovative ecosystems based on hydrocarbons offer opportunities to access funding and optimize resources, such as technologies, mentorships, and networking opportunities. This optimization plays a major role in facilitating innovative solutions for the market and fostering innovation ecosystems. Additionally, technological integration presents significant opportunities for innovative ecosystems based on hydrocarbons. Integration of technologies, such as automation, data analytics, IoT, A.I., and robotics, to improve exploration techniques, optimize production processes, and enhance safety and operational efficiency. Additionally, innovative ecosystems based on hydrocarbons capture new growth opportunities for economic diversification beyond traditional hydrocarbon activities. In addition, collaboration and partnerships between industry, academia, and government institutions enable sharing of expertise, resources, and funding, facilitating research and development initiatives. These opportunities can contribute to the

further development and enrichment of Qatar and other nations whose economies heavily rely on the hydrocarbon industry by fostering the growth of their innovation ecosystems.

Innovative ecosystems based on hydrocarbons are facing several challenges. Industry, academia, and government institutions have different proprieties, which can cause challenges in achieving harmony and arrangement. Establishing shared objectives and effective communication can overcome this challenge. Additionally, due to the rapid pace of technological advancements, developing the required skills and expertise is another challenge facing hydrocarbon-based innovative ecosystems. Developing innovative initiatives and programs to equip and train staff in industry and institutions with the requisite skills for innovation can help bridge the skills gap. In addition, another challenge is mitigating the environmental impact of hydrocarbons, such as emissions, which requires developing and deploying technologies that improve emissions control measures and provide sustainable practices.

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