Journal of Open Innovation: Technology, Market, and Complexity

Article

Exploring the Global Innovation Systems Perspective by Applying Openness Index to National Systems of Innovation

Aram Cho and Sangook Park *

Department of Science Studies, College of Natural Science, Seoul National University, Seoul 08826, Korea
* Correspondence: sangook.park@snu.ac.kr

Abstract: This paper raises the question of whether global innovation systems (GIS), the expanded networks of actors beyond national boundaries, could be a new sibling of innovation systems perspectives. We argue that in today's globalized world, it is idoneous to analyze innovation activities in a global context rather than a national or regional one. To confirm this argument, first, previous research is reviewed to understand how the GIS perspective has emerged and what different aspects have enabled these discussions. Distinct gaps from a body of literature are identified, such as the lack of a united definition, leading causes, and empirical evidence of GIS. With this understanding of the GIS perspective's background, this research aims to overcome the challenge of filling out these gaps using two-stage approaches. The first approach suggests three building blocks of the GIS perspective (global institutions, global actors and networks, and a global knowledge-base). Using the open innovation concept, the second approach measures the openness of national innovation systems (NIS) of the OECD DAC (Development Assistance Committee) member countries to represent the tangibility of the GIS perspective. The paper concludes that the GIS approach would provide us with a valuable viewpoint for analyzing current innovation activities in today's globalized economy as the form of GIS perspective is observed when measured.

Keywords: global innovation systems (GIS); open innovation; national innovation systems (NIS); openness; globalization; institutional convergence

Citation: Cho, A.; Park, S. Exploring the Global Innovation Systems Perspective by Applying Openness Index to National Systems of Innovation. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 181. https://doi.org/10.3390/joitmc8040181

Received: 18 August 2022
Accepted: 2 October 2022
Published: 9 October 2022

1. Introduction

With rapid globalization since the 1980s, diverse innovation activities from exchanging knowledge and technology transfer to research collaboration have been carried out beyond territorial boundaries. In the field of science policy and innovation studies, various innovation systems perspectives have been introduced. The national innovation systems (NIS) perspective, the regional innovation systems (RIS) perspective, and the sectoral innovation systems (SIS) perspective were particularly successful among them. These concepts have been considered as the framework not only for analyzing innovation processes but also for designing systematic policies. However, some innovation perspectives have been criticized for their geographical boundaries as a number of limitations were raised in a territorial context [1–3].

One of the proposals was to improve the NIS perspective by expanding the analytic boundary from national to global [4–9]. Unlike the traditional innovation systems perspective that focuses on spatial or sectoral boundaries, the global innovation systems (GIS) perspective, a newly emerging concept, recognizes the flow of knowledge and innovation creation in the global context. We believe that the globalization of the social and economic environment, as well as the science, technology, and innovation (STI) community, stimulated us to perceive the NIS perspective in a broader sense. Thereby, we find it crucial to understand the basics of the GIS perspective and whether the new concept could position itself as a new sibling of the innovation systems perspective.

Our research on the GIS perspective is not something new in the field of science policy and innovation studies. This very attempt goes back to the early 1990s when there were

extensive discussions on internationalization and globalization of the (national) innovation systems perspective. The latest papers face the challenge of comprehending the mechanism of the GIS perspective, but most of the research is limited to a market-based viewpoint [4–9]. Despite these papers' contributions to the GIS perspective, a number of literature gaps are recognized. To fill out these gaps, this study aims to review the overall related arguments regarding the GIS perspective and identify what building blocks led to its emergence. Furthermore, by adopting Chesbrough's "open innovation" concept and proposing a new measurement framework for the openness of the NIS perspective, this paper explores the possibility of the GIS perspective.

Why, then, is it essential to conduct research on the GIS perspective? Other than the world being globalized, what are the reasons for this perspective to be studied thoroughly? First, as the outburst of the number of multinational enterprises (MNEs) and the innovation driven by them intensifies, it is no longer adequate to apply traditional innovation systems perspectives such as the NIS perspective to the current innovation process. As MNEs rely on a borderless economy, their stage for innovation activation is mainly beyond territorial boundaries. Thus, the GIS perspective is the most applicable framework for understanding MNEs' flow of innovation creation.

Second, the trend of pursuing open innovation in the industry—with the growing demand for utilizing foreign innovation actors and activities in the field of STI—has raised expectations for the innovation process and networks to be acknowledged in a global setting. Since Chesbrough [10] introduced the open innovation concept, although his book mainly relies on actors' innovation collaboration within a country, the idea proliferated on a global scale, in line with partnership arrangements between innovation actors from abroad.

Third, the voices requiring responses to the Global Grand challenges are rising substantially throughout the world, asking for global-level actions [11]. Despite globalization having induced an increase in trade volume and the advancement of technology by significantly impacting the world's economy, unexpected environmental and social side-effects have also been generated. Natural disasters due to global warming and the dramatic increase in the income gap between the Global South and the Global North have resulted in the world and its leaders self-reflecting on their past behaviors. One of the suggested ideas on how to solve the world's challenges is the reestablishment of the role of STI. In the past, the primary purpose of science and technology was to enrich countries and their people; however, the directions of public investment in STI have changed towards solving the current socio-economic issues that humanity faces [12]. This new perception of STI has greater potential synergy when the world contributes together; thus, it is essential to have the GIS perspective when comprehending the world's efforts to solve global challenges.

Fourth, the need to realize Sustainable Development Goals (SDGs) has encouraged and stimulated cooperation between countries, especially in the field of science and technology. Globalization brought economic gaps, but it also caused capacity differences in science, technology, and innovation among countries of different income groups. Through development cooperation such as Official Development Assistance (ODA), the journey to achieve SDGs may be shortened. Furthermore, support from advanced economies could enhance the science and technology capacities of developing nations.

The main research questions for this paper are as follows:

- *Research Question 1: How can GIS indicators be measured by applying open innovation theory?*
- *Research Question 2: Is it possible to have the global innovation systems perspective as the new sibling of innovation systems perspectives by adopting openness from the open innovation concept?*

To answer these questions, the structure of this paper is as follows. In the first part of the paper, we review a wide range of literature to detect the limitations from previous research. From well-known concepts of innovation systems perspectives and open innovation to the existing discussions on global innovation systems perspectives are reviewed. For comprehensiveness, this paper considers the internationalization and globalization of the NIS perspective as a synonym of the GIS perspective. From this

viewpoint, we confirm distinct gaps in reviewed works of literature, such as the lack of a united definition, leading causes, and empirical evidence of the global innovation systems perspective. The gaps are filled out using two-stage approaches. Part three introduces our research framework, the concept of the global innovation systems perspective, and the methodology used to explore its possibility. In part four, the first-stage (theoretical considerations) approach is discussed in detail. The three building blocks of the GIS perspective, namely, the global institutions, the global actors and networks, and the global knowledge-base are identified. For the second-stage approach, quantitative analysis is used in part five by highlighting the result of the NIS openness measurement of twenty-nine OECD (Organisation for Economic Co-operation and Development) DAC (Development Assistance Committee) member countries and presenting their features using our proposed framework. In this stage, we discover that the openness of NIS has been expanding gradually, and when NIS openness is compared with NIS performance, it shows an apparent correlation. This result provides a significant implication that it is crucial to have better NIS performance and broader NIS openness for global innovation to grow. The paper concludes that the GIS approach would provide us with a helpful viewpoint for analyzing current innovation activities in today's globalized economy as the form of GIS perspective is observed when measured.

2. Literature Review

As mentioned in the previous section, in this part of the paper, we will go through the existing literature on related topics. Firstly, research on well-known concepts of innovation systems perspectives will provide some background on overall perspectives on innovation systems. Secondly, the literature on open innovation theory will provide greater understanding on part of the quantitative method (measuring the openness of NIS) of this paper, which will be introduced later. Lastly, the existing discussions on the GIS perspective will help us detect the limitations from the previous research and provide us with the opportunity to have our own conceptualization of the GIS perspective.

2.1. Innovation Systems Perspectives

Since Christopher Freeman [13,14] first introduced the concept of innovation systems perspectives, the definition was later elaborated by other innovation scholars [15–18]. Using the case of Japanese innovation under project SAPPHO (Scientific Activity Predictor from Patterns with Heuristic Origins), Freeman stated that "in Japan, industries, universities, and research institutes not only interact with one another but are organically connected within a strong government link, which leads to the technological innovations. It seems that the country as a whole is one big system for innovation." With this thought in his head, Freeman defined the NIS perspective as "the network of institutions in public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" [14]. His NIS perspective clearly shows that the range of subjects in the analysis is within a country. Later, the scholars in science policy and innovation studies from the University of Sussex's science policy research unit (SPRU) and the University of Manchester's policy research in engineering, science, and technology (PREST) department redefined the NIS perspective. Bengt-Ake Lundvall, for instance, defined the national innovation systems perspective as "the elements and relationships which interact in the production, diffusion, and use of new, and economically useful knowledge . . . and are either located within or rooted inside the borders of a nation-state" [15,19]. Later, the OECD selected the perspective as the main framework for STI policy and led its member countries to apply the concept to analyzing and setting the foundation for their policy. This allowed the national innovation systems perspective to be diffused worldwide.

The country-based innovation framework was further adopted by international organizations, supranational groups, and private sectors such as the World Economic Forum (WEF), the European Commission, and Bloomberg to measure each country's innovation competitiveness. Other forms of innovation systems perspectives were introduced to

overcome the limitations of the national innovation systems perspective. The regional innovation systems perspective by Cooke [20] expanded the discussions on industry clusters in geography studies, while the sectoral innovation systems perspective by Malerba [21] influenced the economics of the industry life cycle. However, the national innovation systems perspective stands still and is positioned as the basis of the innovation systems perspective. Nevertheless, the flexibility of the concept and its simultaneous formation, developed by a number of scholars, is an ongoing issue from the national innovation systems perspective. Along with the emergence of globalization, it is essential to reconsider whether the NIS perspective is an idoneous framework for every country or not [2,22].

2.2. Open Innovation

In the past, when the entire innovation creation process of a company was available within a firm's boundary, the development and commercialization of technology, the recruitment of talent, and the systematic management of intellectual property rights (IPRs) in order to prevent one's novel technology leaking out to its competitors were all under control at the firm level. This strategy is called the "closed innovation model" [10]. However, not all technologies developed in a firm were successfully commercialized or generated monetary profit, and intensified competition in the industry due to the globalized economy led companies into crisis. As advanced technology-based products became complex, the managers of the firms realized that there are too many technical limitations and risks for a single company to handle. Additionally, to save labor costs, outsourcing became a new norm for the industry. As a result, the scope of outsourcing expanded from simple assembly to a portion of product research and development [10,23–26].

In his book *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Chesbrough [10] identified that more innovation could be created when firms open their innovation sources to others and vise-versa. He named this unconventional strategy "open innovation" and found out that the source of knowledge for a firm may vary from innovation actors, such as public research institutes, universities, suppliers and consumers, to its competitors, and it is the official or unofficial collaboration between these actors that generates open innovation [10]. This new strategy model is highly considered as an essential tactic for firms for the following two reasons. First, both the firm and its competitors faced limitations in catching up with the rapidly changing technology trends on their own and felt the need to adopt technologies from outside that were in demand. Second, a technology that is developed by a firm but fails to commercialize could achieve success in a different firm by transferring it. The firm that transfers the technology would receive an appropriate fee, and by doing so, both parties would gain profits [10,23,27–30].

The ways of conducting open innovation vary as well. From in-licensing, out-licensing, and joint R&D (research and development) investment to adopting venture capital, it is vital for actors to remain flexible regarding accepting different methods [10,23,31,32]. Licensing IPRs, for instance, is an open innovation method that formally brings resources and knowledge from outside and integrates them into the organization's innovation process, and it is why the strategic management of IPRs is required.

Apart from flexibility being one of the characteristics of open innovation, other unique facts are related to this theory. Firstly, before Chesbrough introduced open innovation, it was already used between firms as a business strategy, meaning it is not something new [33]. Secondly, as Dahlander and Gann [34] and Lichtenthaler [35] have already shown, the boundary between open and closed innovation is ambiguous. In a real economy, it is much more common to see these two innovation strategy models combined simultaneously in the process of knowledge creation.

To sum up, open innovation is not a new concept, but rather, an innovation strategy that has evolved with social and economic changes. Although Chesbrough's book mainly focused on the open innovation of U.S.-based firms' innovation-generating processes, his theory can be expanded and utilized when explaining it on a global scale in today's

globalized economy. Within this context, this paper will use the open innovation concept to investigate the possibility of the global innovation systems perspective.

2.3. From Internationalization to the GIS Perspective

As briefly mentioned in the introduction, we are not the very first ones to explore the concept of the global innovation systems perspective. Discussions related to this particular perspective start from the 1990s, and it is noteworthy that it has been mentioned in different terminologies such as the internationalization of the (N)IS perspective or the globalization of the innovation systems perspective. It has been less than a decade since the term "GIS perspective" stood out in the related research.

Niosi and Bellon [4] are some of the first scholars to capture the changing forms of the national innovation systems perspective. As they understood that the openness of NIS is due to the globalization and internationalization of science and technology, their study listed six different innovation activities, such as the research and development by MNEs and international technology transfer, to identify the global interdependence of the NIS perspective. They argued that it is national policy that influences a country's NIS openness. Archibugi and Iammarino [5] proposed a taxonomy and indicators for tracking down the globalization of innovation in a similar context. A wide range of indicators such as high-technology trade and the inflow of R&D by multinational enterprises were introduced; however, due to insufficient data, they showed limitations by setting subject countries and a time frame for the analysis that were incoherent. Carlsson [6] attempted to conduct a literary survey with the topic of internationalization of the innovation systems perspective. His paper emphasized the growing attention given to the internationalization of the NIS perspective and RIS perspective. However, he concludes by pointing out that despite the internationalization of the innovation systems perspective, the previous pieces of literature underline that the country-specific characteristics still exist; thus, it is the national policy that should be considered most importantly. Fromhold-Eisebith [36] argued for the interdependence of the RIS perspective and NIS perspective, and introduced the international innovation systems (IIS) perspective as an upper scale of the RIS and NIS perspectives.

Since the 2010s, unlike the 1990s when the studies were under the frame of the national innovation perspective, the term "global innovation systems perspective" started to gain more attention as the main research topic. Binz and Truffer [7] detected a limitation in explaining the innovation systems perspective using traditional approaches due to today's dynamic innovation interactions, and argued that the GIS perspective could solve its problem. For this matter, they designed a conceptual structure and a typology of four generic configurations of GIS perspective and identified different innovation actors involved in the system from an industry-sensitive viewpoint. In their newest paper, based on their proposed configuration of the GIS perspective, the authors provided an elaborate implication for governance on globalized innovation systems perspective [8].

With regard to measuring the presence of GIS, Lee et al. [9] attempted to do so by using the case of a science and technology collaboration between South Korea and the United Kingdom. Using the open innovation concept, a new analytical framework was designed to diagnose the degree of cooperation between the subject countries. They argued that strategic open innovation at the national level could expand the NIS perspective to the GIS perspective. However, this paper faces limitations when tracking down the openness of NIS for countries that do not actively collaborate with foreign countries in the field of STI.

From these collective studies, we recognize that the concept of the global innovation systems perspective evolved from grasping the world's changing status towards globalization, and thus, allowed proactive discussions on expanding the conventional innovation systems perspective. The existing body of literature is meaningful in its own way as the authors search for the GIS perspective by proposing their own taxonomies or structures, with which countries cooperate beyond borders. The latest papers regarding the GIS perspective utilized the analytical framework proposed by Binz and Truffer's 2017 [7] to

demonstrate their new arguments [37,38]. Nevertheless, all the previous literature failed to clarify "why GIS perspective could be discovered in the first place" and "what is the logic behind it?" For this matter, we have identified three distinctive building blocks causing the GIS perspective: global institutions, global actors and networks, and the global knowledge base. This will be explained in detail in the latter part of this paper.

To summarize, first, most of the literature analyzed the GIS perspective or the openness of the NIS perspective with either a market-or collaboration-oriented framework. It is true that globalization led to an expansion of the science, technology, and innovation markets and increased the volume of STI collaborations. These facts were represented by indicators such as the trade volume, the number of foreign direct investments (FDIs), the number of collaboration projects, the migration of STI talent, etc. However, these indicators and market-/collaboration-oriented frameworks lack an explanation of why openness is detected in the national innovation systems perspective.

Second, despite the literature focused on discussing openness and internationalization, the national innovation ecosystem was emphasized fairly instead of suggesting policy implications in a global context. The studies failed to understand the global innovation systems perspective in a holistic manner and did not share a common understanding of what constructs the global innovation systems perspective. The research rather focused on the characteristics of each country's innovation systems with a policy-oriented perspective to discuss the importance of promoting the nations' innovation or even limited global innovation systems perspectives as a "network" of multiple national innovation systems.

Third, apart from Archibugi and Iammarino [5] and Lee et al. [9], studies on measuring the openness of national innovation systems, and hence, measuring the global innovation systems, are still lacking. Previous efforts to measure the openness of national innovation systems are incoherent with their indicators, targeted countries, and time frames, thereby making it difficult to apply the surveys to non-selected countries. In order to fill out this gap, we propose a new systematic measurement framework for the openness of national innovation systems in the next part of the paper.

Fourth, while the trends in studying the global innovation systems perspective are growing, it is not easy to find a consistent flow of literature, unlike the mainstream innovation systems perspective. For instance, the only literature that Binz and Truffer [7] and Lee et al. [9] managed to overlap was a paper by Niosi and Dosi [4]. For the national innovation systems perspective, for example, discussions by Freeman and Lundvall played a pivotal role; however, there is no flow but rhetoric for research on the GIS perspective, thus causing fragmentation when listing related papers. Therefore, as will be mentioned in sections four and five, we would like to solve this severance problem of the GIS perspective by identifying the concept and measuring the openness of NIS.

3. Analytical Framework

3.1. Conceptualization of the GIS Perspective

As reviewed in the previous section, there are several pieces of literature on the GIS perspective using different terminologies, from the internationalization of the NIS perspective to the globalization of the innovation systems perspective. These research papers provide implications by capturing the global innovation systems perspective and providing empirical evidence of the GIS perspective. Nevertheless, they do not explain what generates the global innovation systems perspective and how we should perceive it. So, what exactly is the GIS perspective? What are the building blocks of this perspective? Our comprehension of the global innovation perspective is as follows:

> *The convergence of institutions and the globalization of scientific knowledge enabled country-based innovation actors to be located at a global level, leading to the collapse of boundaries of the national innovation systems perspective.*
>
> *Therefore, the openness and the expansion of the national innovation systems perspective, in other words, the global innovation systems perspective, should be considered as a new sibling of the innovation systems perspective.*

Based on our conceptualization, we also detected three building blocks of the GIS perspective, which are the global institutions, global actors and networks, and global knowledge base (see Figure 1). These building blocks will be further explained in the next section (see Section 4).

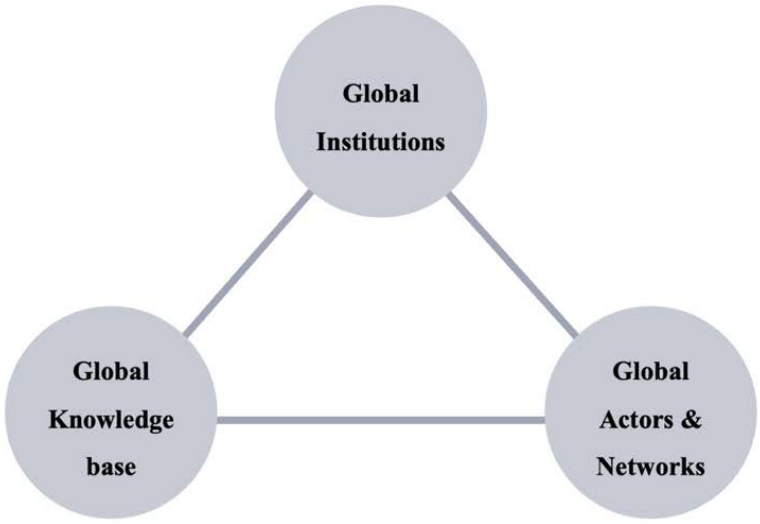

Figure 1. Three building blocks of the GIS perspective.

3.2. Methodology

In this paper, two-stage approaches, both qualitative and quantitative, are used. In the first stage, as the GIS perspective is still undefined, we firstly use a qualitative approach by providing an in-depth understanding of the GIS perspective's background. As a theoretical consideration, three building blocks of the GIS perspective are reviewed in detail in Section 4. For the first building block, the globalization of institutions, we list the driving forces of institutional convergence and determine how these global institutions lead to different types of innovation. The second building block, the global actors and networks, is illustrated with a proposed structure of the GIS perspective. In this stage, we attempt to show the relationships between the national innovation systems perspective, the global innovation systems perspective, and the actors involved in each system, and highlight the importance of the globalized institution. Lastly, the third building block, the global knowledge base, is discussed with the uniqueness of science, technology, and innovation and its latest trends.

In the second stage, to verify the empirical evidence of the global innovation systems perspective, a qualitative approach is used for measuring the openness of NIS. As mentioned earlier, one of the primary purposes of this paper is to measure the openness of NIS of the subject countries and capture the overall openness of NIS, which is equivalent to GIS, and compare each countries' NIS openness to their NIS performance to analyze their relations. This, in other words, will answer our first research question: how can GIS indicators be measured by applying open innovation theory? In order to proceed with this process, we propose a new framework for measuring the openness of NIS under the foundation of different types of innovation (see Section 4.1).

Table 1 indicates the proposed measurement framework for the openness of national innovation systems. This framework consists of eight indicators under three different types of innovation. Different types of innovation, from inward and outward to collaboration, are considered as the source of NIS openness. Using data from the OECD and the World Bank, we were able to list eight indicators representing each type of innovation.

Table 1. Proposed measurement framework for the openness of the national innovation systems.

Types of Innovation	Indicators
Collaboration for Innovation	Patents with foreign co-invention
	Science, technology, and innovation (STI)-related Official Development Assistance (ODA)
Inward Innovation	Charges for the use of intellectual property, payments
	GERD (gross domestic expenditure on R&D) financed by the rest of the world
	BERD (business enterprise expenditure on R&D) financed by the rest of the world
Outward Innovation	Charges for the use of intellectual property, receipts
	Medium- and high-technology exports
	Triadic patent families

The first type of innovation, collaboration for innovation, has two indicators: patents with foreign co-invention and the CRS (Creditor Reporting System) code in science, technology, and innovation. The former indicator was selected to capture the subject country's innovation actors' willingness to cooperate with foreign actors. As an indicator representing international cooperation in patent activities, the index was measured by "the share of patents with at least one foreign co-inventor in total patents invented by resident(s) of country" [39]. The latter indicator was chosen to include innovation cooperation involving developing countries. Due to difficulties securing developing countries' data for measuring the openness of NIS from our sources, as an alternative, the CRS codes related to STI were applied. The OECD DAC "maintains various code lists which are used by donors to report on their aid flows to the DAC databases" [40]. As shown in Table 2, we identified nine CRS codes as part of STI. All the indexes from nine CRS codes (the Official Development Assistance amount in millions of USD) received the same weight (1/9), and the overall average was considered as the whole index for STI ODA. The aim of this particular procedure is to mitigate the limitation of this research in excluding developing countries as the subject of this study.

Table 2. Science and technology innovation related OECD CRS codes.

CRS Code	Sector
11182	Educational research
12182	Medical research
23182	Energy research
31182	Agricultural research
31282	Forestry research
31382	Fishery research
32182	Technological research and development
41082	Environmental research
43082	Research and scientific institutions

The second type of innovation, inward innovation, has three indicators, and they all represent innovation activities from abroad but that affect internal innovation. The first indicator for this innovation type is payments for the use of intellectual property (IP). The index for this indicator shows the "payments between residents and nonresidents for the authorized use of proprietary rights and the use, through licensing agreements, of produced originals or prototypes and related rights" in current USD [41]. In other words, the index for payments for the use of intellectual property indicators states the commitment of the subject country's innovation actors in learning and adopting knowledge from overseas. The second and third indicators are similar because they are both concerned with expenditure on research and development that is financed by the rest of the world. GERD stands for gross domestic expenditure on research and development, while BERD stands for business enterprise expenditure on research and development. If a country shows relatively higher

figures for these two particular indicators, this points out that the subject country is favored by foreign investors and is entitled to the source of innovation from abroad.

The third type of innovation is outward innovation. This specific type of innovation, which includes three indicators, is generated within the country, but the outcome involved is beyond the border. Similar to the inward innovation type, outward innovation contains an indicator related to charges for the use of intellectual property. The receipts for the use of intellectual property indicate that the index is the sum of profits that the innovation actors in a country gain when actors from abroad use their intellectual properties. Another indicator for the outward innovation type is the share of medium- and high-tech manufactured exports in total manufactured exports. While the receipts for the use of intellectual property include the flow of the direct use of technology, the share of medium- and high-tech manufactured exports covers the indirect use of technology and the source of innovation. The last indicator is the number of triadic patent families. The OECD [39], one of the main sources for our quantitative research, defines triadic patent families as "a set of patents filed at three major patent offices which are the European Patent Office (EPO), the Japan Patent Office (JPO), and the United States Patent and Trademark Office (USPTO)." We find the number of triadic patent families suitable, as the sum shows the overall direct outflow of innovation of the subject country.

One of the unique aspects of the measurement framework for NIS openness proposed in this paper is that it did not include inward and outward foreign direct investments as its indicators. Indicators related to FDIs have a strong advantage with sufficient data available. They are also suitable when identifying a country's attractiveness as the destination for investments, or when detecting a country's willingness to invest abroad. However, FDI-related indicators contain limitations such as difficulty classifying the investment's technology level (whether it is targeted towards low-level technology with labor-based assembly or high-technology with college-level-educated manpower). Therefore, inward and outward FDIs are excluded from this paper, and indicators such as IP payments and receipts, GERD and BERD financed by the rest of the world, and the percentage of medium- and high-tech exports are used as alternatives.

Based on the proposed measurement framework, we were able to select twenty-nine countries as the subjects for this research. The requirements for the subject countries were: first, all the data from Table 1 should be available, and second, for our later comparison with the NIS performance, the country should be listed as one of the countries in the Bloomberg Innovation Index. After gathering all the accessible data and checking whether the data availability was above 80%, we set the measurement time frame from the year 2002 to 2018.

For the measurement, we benchmarked the European Commission's European Innovation Scoreboard (EIS). The European Innovation Scoreboard "provides a comparative analysis of innovation performance in E.U. countries, other European countries, and regional neighbors in order to help countries assess relative strengths and weakness of NIS identify the areas they need to improve" [42]. The scoreboard annually reports the result of the assessment and its methodology. In particular, the methodology report is accessible freely on the internet, and it is relatively simple—due to every indicator being emphasized equally—to understand the mechanics; this is why we measured NIS openness based on EIS.

As the indexes from the proposed measurement framework's eight indicators showed significant differences in their volume, two-stage normalization methods were adopted. Firstly, we used a logarithmic scale for all the indexes. Secondly, each figure was calculated using Z-score standardization, a method which reveals where a particular country's index is located. Thirdly, after the two-stage normalization, the figure was added to the absolute minimum and multiplied by 100 to be simplified in a score format. Lastly, every eight modified indexes of a country were multiplied and divided by eight on a yearly basis, in order to put the same weight on each indicator.

$$X = \log(D) \quad (1)$$

$$Y = ((X - avg))/stdev \quad (2)$$

$$Z = \{(Y + abs(min)\} \times 100 \quad (3)$$

$$CA = 1/8\{PCT(z) + STI(z) + IPP(z) + GERD(z) + BERD(z) + IPR(z) + MHE(z) + TPF(z)\} \quad (4)$$

To analyze the correlation between NIS openness and performance, the Bloomberg Index was used[1] to substitute the NIS performance. The Bloomberg index measures a country's innovation based on seven fields: R&D intensity, manufacturing value-added, productivity, high-tech density, tertiary efficiency, researcher concentration, and patent activity. There are several frameworks measuring the innovation performance of selected countries; however, we find Bloomberg's index most compelling as its indicators do not overlap substantially with our proposed NIS openness measurement framework's indicators.

4. The Building Blocks of GIS

4.1. Global Institutions

Since DiMaggio and Powell [43] introduced the concept, there have been active discussions on institutional convergence. A number of causes define what led to institutional convergence; however, it is always globalization that underlies the theory. Institutional convergence is no exception for STI institutions, as it is highly affected by globalization. Some of the driving forces of STI institutional convergence are international organizations, policies from developed/neighboring countries, and science policy and innovation studies.

As shown in the figure below (see Figure 2), international organizations such as the OECD and the European Union have introduced STI policy frameworks, resulting in convergence and the globalization of institutions. These organizations tend to adopt coherent yet effective STI-related models and introduce them to their members, and the NIS perspective of the OECD is a perfect example. Additionally, their annual evaluations of innovation have led their member countries to set specific frames and goals when planning STI policies. Moreover, the spread of organizations selected STI models by conducting international conferences or meetings targeted towards STI policy experts and country representatives, for those who have the authority for decision making in their countries [44].

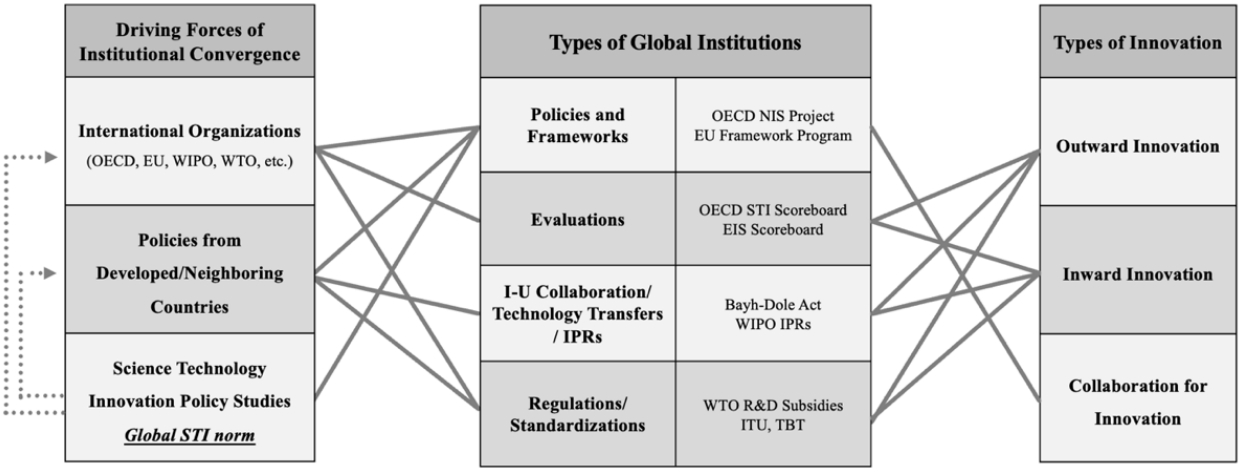

Figure 2. The global institutions of STI and its mechanisms.

As shown in the figure below (see Figure 2), international organizations such as the OECD and the EU have introduced STI policy frameworks, resulting in convergence and the globalization of institutions. These organizations tend to adopt coherent yet effective STI-related models and introduce them to their members, and the NIS perspective of the OECD is a perfect example. Additionally, conducting annual evaluations on innovation, such as the STI Scoreboard of the OECD or the European Innovation Scoreboard of the European Commission, is another way to promote the implementation of the chosen STI models and lead their member countries to set specific frames and goals when planning

STI policies. Other methods such as conducting international conferences and providing consulting services to STI policy experts or country representatives, for those who have the authority for decision making in their countries, are used to expand the organizations' selected STI models [44]. In addition, twenty-four treaties set by the World Intellectual Property Organization (WIPO), for instance, to protect intellectual property rights, became the standard for IPR-related regulation globally. The World Trade Organization (WTO) also set agreements regarding the allowable scale and items for subsidies, prompting the member countries to follow the restrictions, thus creating new rules [45].

The developed or neighboring countries' STI policy acts are another driving force for institutional convergence. In the field of public policy, governments tend to benchmark countries with leading policies. In the case of STI policy, the United States was considered the pioneer with ideal STI policies. The Bayh-Dole Act, which built an industry–university collaboration system, encouraged two parties from different sectors to cooperate on their research activities, and later, the idea was adopted by other countries [46–48]. Germany and Japan succeeded in the endeavor, adopting systematic policies, followed by the Western and Northern European countries. In the 1960s, the Asian Tigers aggressively planned their industrial policies, and in this process, the policies from the United States, Germany, and Japan were adopted simultaneously and localized deliberately. However, the benchmarking of STI policies from neighboring countries does not occur sequentially. Finland, for instance, imitated STI policies from Sweden and the United States by implementing related plans, and established a science and technology ministry to gain competitiveness [49].

The field of science policy and innovation studies is the last yet the most crucial driving force of the convergence of STI policies. The academic community for science policy and innovation studies is strongly gathered among SPRU from the University of Sussex, PREST from the University of Manchester, and DRUID (Danish Research Unit for Industrial Dynamics). Scholars from these institutes and their ideas are now spread worldwide, allowing a solid yet common understanding of policy issues and solutions [50]. This "common understanding" leads to the global norm and provides helpful directions for STI-related policies.

The three driving forces of institutional convergence—the international organizations, policies from developed/neighboring countries, and the science policy and innovation studies community—generate various types of STI global institutions from frameworks, evaluations, regulations, and standardizations. The end-products of STI global institutions from these driving forces are the different types of innovation, namely outward innovation, inward innovation, and collaboration for innovation, the mainframe for our proposed NIS openness indicators (see Figure 2).

4.2. Global Actors and Their Networks

In the previous section, we identified the driving forces and their outcomes for global institutions. Now we move onto the global actors and networks which describe the structure of the global innovation systems perspective. From the national innovation systems perspective, the three key actors—universities, industry/firms, and public research institutes—interact with one another under the national STI policies. How, then, is it different for the GIS perspective?

Figure 3 displays the structure of the GIS perspective. As the global innovation systems perspective concept relies on the borderless interaction between innovation actors, the boundaries for the national innovation systems perspectives are marked with dotted circles. In contrast, the boundary for the GIS perspective is indicated with a lined circle. One of the significant differences in the GIS perspective compared to the conventional structure of the NIS perspective is that a new actor, the international organization, is included. The new actors are linked with each country's national institutions and connected, showing their range of influences. Another difference is that the global institution is located in the center of the GIS perspective, which underlies the basis by affecting the actors by promoting their interactions.

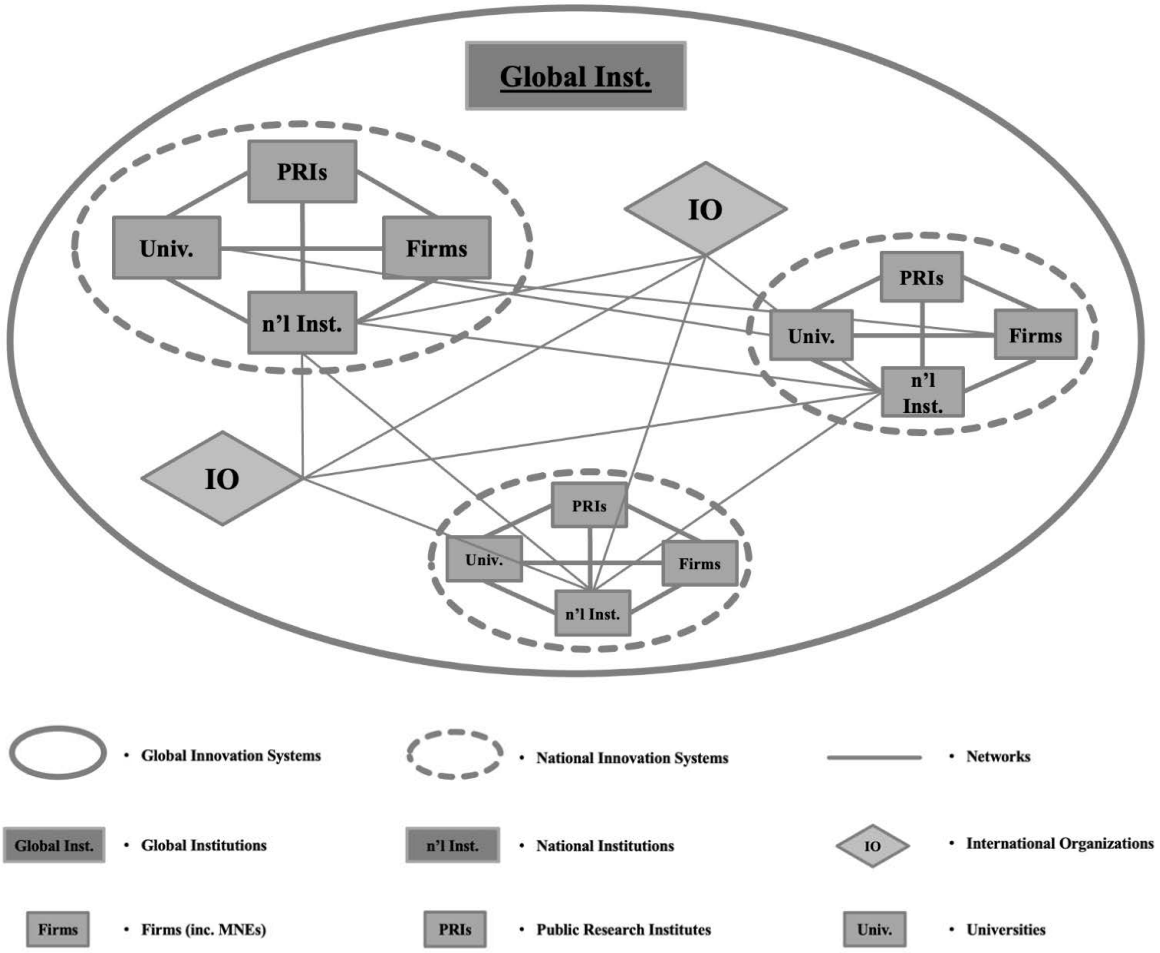

Figure 3. The structure of the global innovation systems perspective.

Different sizes of national innovation systems perspectives indicate the activeness of the innovation actors in a country, meaning the top-left NIS perspective is the most innovative country, while the one in the bottom center is the least innovative. Therefore, while the most innovative country's universities and firms show several linkages with other countries' actors, for the least innovative country, apart from national institution, its actors mainly interact with each other within the country boundary. It is also interesting to note that the national institutions from each national innovation systems perspective form a network, supporting the second driving force of the institutional convergence and the policies from developed/neighboring countries.

4.3. Global Knowledge Base

The last element comprising the GIS perspective is the global knowledge base, and this can be discussed with the characteristics and trends that science and technology entail. Firstly, science as a public good is noncompetitive. In academia, novel findings are published in international journals, presented in conferences, or even spread to informal researcher communities. Scientific knowledge, first introduced or accepted by the scientific community as a new paradigm, is standardized in the process of diffusion. In the case of biology, despite a significant difference in the capacity for utilizing it among countries, it relies heavily on knowledge from life science studies shared worldwide.

Secondly, the globalized trends in technology are intensifying the expansion of the NIS perspective. Since the 1980s, including ICT (Information and Communications Technology), technologies considered as part of the fourth industrial revolution are leading the globalization of technology. Kondratiev waves (also called as long waves) and the

techno-economic paradigm are described by Freeman and Perez [51]. They have already shown in their studies that the trends for technology are now world-specific, and there is no doubt that this tendency will continue.

Thirdly, a new megatrend of research and development has been introduced and enforced. Until the 1970–1980s, the primary purpose for a government to invest in R&D was to create scientific knowledge and bring economic prosperity for their people. However, as advanced science and technology have resulted in some irreversible side-effects, the need to set and accomplish global challenges has been raised along with the SDGs by the United Nations. Now, the term "sustainable development" is considered one of the main themes when it comes to planning R&D projects, and Innovation Policy 3.0 by Schot and Steinmueller [12] and the Mission-Oriented Innovation Policy by Mazzucato [11] represent these trends.

5. Findings and Discussion

Based on our qualitative research and the proposed methodology introduced in previous sections, we were able to verify the status of the GIS perspective. This section will show the main quantitative findings of the paper (see Figure 4).

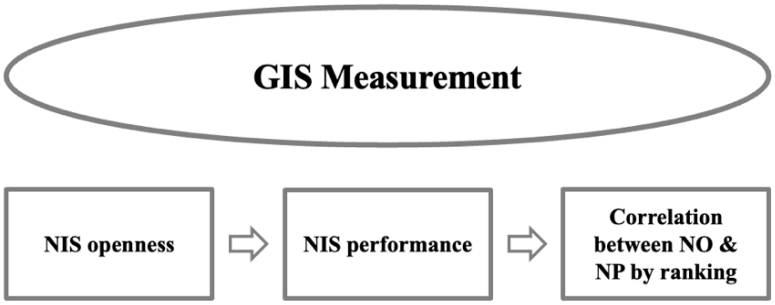

Figure 4. The flow of GIS Measurement.

As this paper understands the GIS perspective as "the openness and the expansion of the NIS perspective", the first step for GIS measurement attempts to find the overall average of the subject countries' NIS openness (see Figure 5). The second step obtains the NIS performance of the subject countries and analyzes a correlation between NIS openness and performance by ranking them (see Figure 6). Through this process, we will be able to very whether the globalization and the gradual expansion of NIS led to GIS (as a new sibling of an innovation systems perspective).

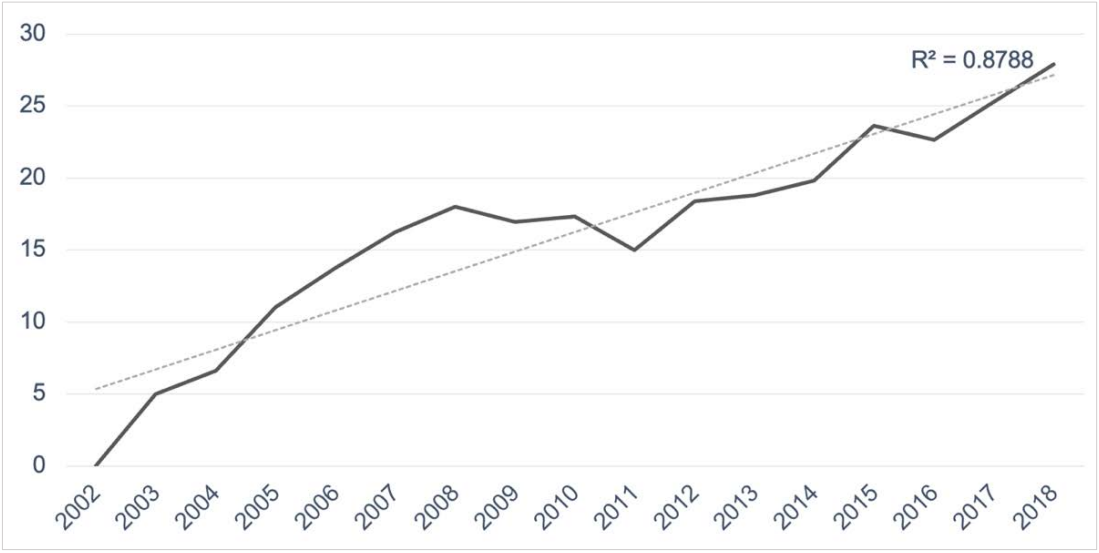

Figure 5. The overall average of the subject countries' NIS openness.

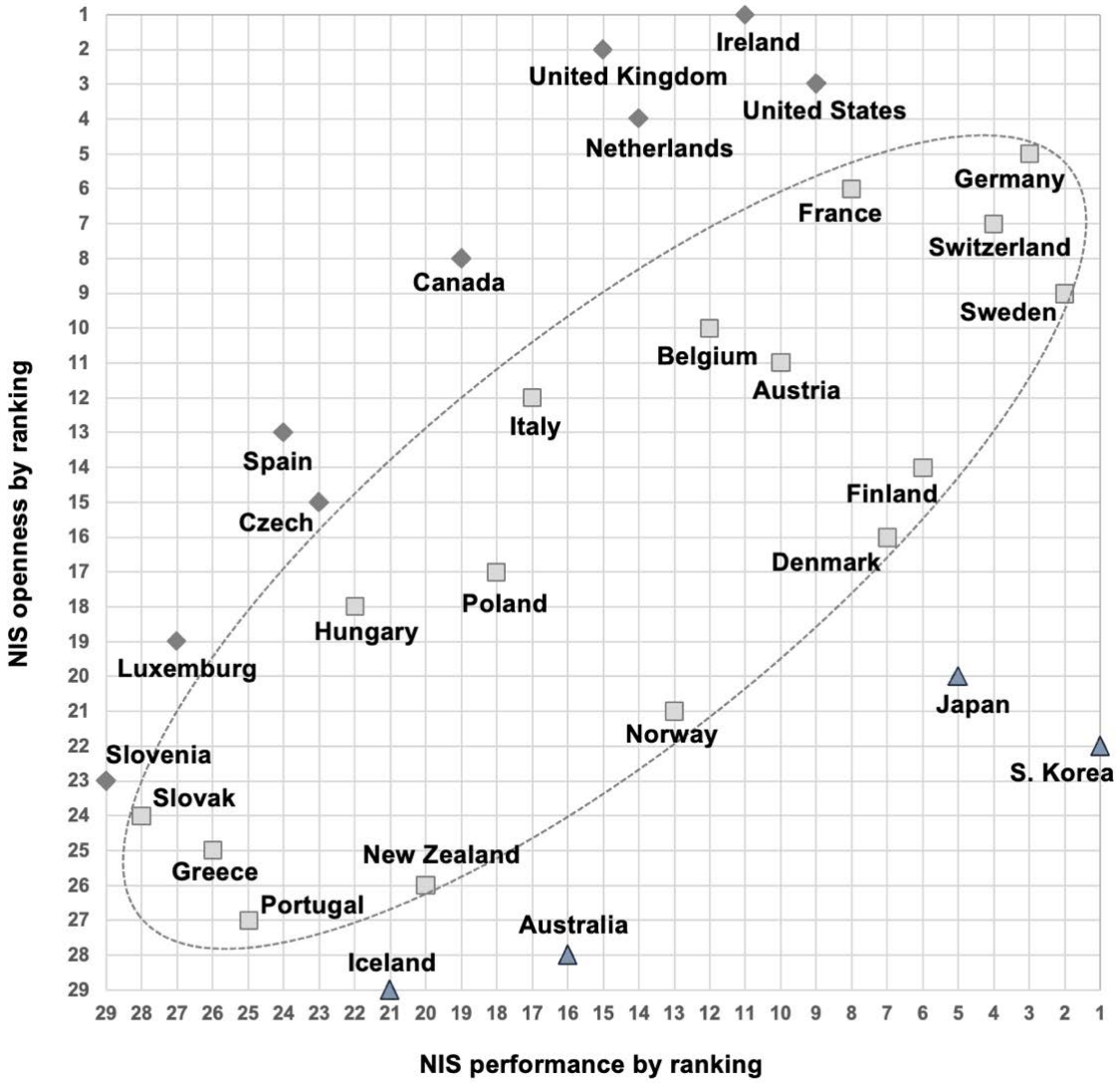

Figure 6. The correlation between NIS openness and NIS performance.

The overall average of the subject countries' NIS openness highlights that the openness increases substantially with an R-squared value of 0.8788 (see Figure 5). In detail, while the NIS openness' overall average peaks in 2008, it shows a slight decrease until 2011. This could be explained as the aftermath of the 2008/2009 financial crisis. From 2011, NIS openness shows a sharp increase from 15 to almost 30. The global average could show another down-fall from 2020 due to the ongoing COVID-19. However, the overall figure confirms that for the last 15 years or so, there has been a great level of NIS openness. In summary, the growing trends of NIS openness support the concept of the global innovation systems perspective.

In Table 3, the overall average of the subject countries' NIS openness is re-measured using the absolute minimum of the total index of both the overall average and each country's average from 2002 to 2018, and multiplied by 100. Table 3 represents the comparison between the overall average of NIS openness and ten major innovative countries. Apart from East Asian countries such as South Korea and Japan, Western and Northern European countries and the United States showed outstanding NIS openness. While most of the countries in Table 3 have a steady increase in their NIS openness over the course of time, South Korea shows fluctuation with a sharp increase between 2011 and 2018.

To better understand NIS openness, we compared the index of NIS openness with NIS performance. We used the Bloomberg Innovation Index of 2018 as a substitute for

NIS performance, and both figures were ranked as of 2018. Figure 6 presents a correlation between NIS openness and NIS performance, and we were able to cluster twenty-nine subject countries with distinctive features.

Table 3. The NIS openness comparison: overall average vs. ten major innovative countries.

	2002	2004	2011	2018
Austria	142.41	134.10	145.90	151.11
Denmark	125.63	124.23	124.18	135.06
Finland	66.17	68.89	110.90	138.73
France	163.14	175.94	177.05	177.85
Germany	127.89	133.82	155.16	181.05
Japan	83.75	84.22	86.31	103.69
S. Korea	45.49	60.14	30.61	96.02
Sweden	128.10	139.23	155.43	167.09
Switzerland	142.80	134.27	185.60	176.99
United Kingdom	199.30	194.65	199.82	200.98
United States	166.71	169.87	177.21	195.73
Global Average	101.98	108.60	116.97	129.87

The first group, the sixteen countries inside the dotted circle (square dots), shows a correlation between NIS openness and NIS performance. The upper-right part of the circle mainly includes Western and Northern European countries. The lower-left part of the circle, countries with low ranks in both NIS openness and performance, are primarily from Eastern and Central European countries. This group, in general, did not attain the global average from most of the indicators except two indicators of the inward innovation type (GERD and BERD financed by the rest of the world). This result could be interpreted as the world finding this group attractive for finance with its affordable investment fees.

The countries with diamond dots, the nine countries located above the dotted circle, are group two. These openness-oriented countries show a notable figure for openness. Ireland, for instance, the number one country for openness, has outstanding figures for seven indicators from the NIS openness measurement framework. The medium- and high-technology exports were the only indicator that Ireland did not meet the overall average. This group's countries, overall, share a common feature in that there are active inflows of innovation activities across the border and interactive actors are involved.

Group three, the four countries with triangle dots, located below the dotted circle, are classified as performance-oriented countries. This group shows unique features from each indicator. Two countries, Japan and South Korea, have a significantly higher index among five indicators, namely the number of triadic patents, ODA, IP payments and receipts, and medium–high-technology exports. The countries have a below-average index for categories such as patents co-invented with foreigners, GERD, and BERD financed by the rest of the world. From this, we may assume that these countries obtained an advantage in opening their innovation systems by transferring their own STI knowledge to developing countries and enhanced their collaboration capacities. Strategically, they have acquired a source of innovation by either exporting or importing technologies from their competitors.

From this analysis, we may conclude that there is a relevance between NIS openness and NIS performance. NIS openness and performance, however, do not correlate all the time, as shown in groups two and three. Nevertheless, it is possible to draw policy implications for each group. First, countries with low NIS performance from group one should set a strategy to opening their NIS and perform better in the future. Countries in group two could take NIS openness as a tactic to boost their NIS performance by utilizing ongoing openness-related activities. Lastly, countries in group three need a plan to open NIS strategically for higher NIS performance.

6. Conclusions

This study attempted to explore the possibility of the global innovation systems perspective by adopting open innovation theory across borders and overcoming the closedness and limitations of the NIS concept by measuring openness at the national level. Three building blocks of the GIS perspective (global institutions, global actors and networks, and the global knowledge base) were identified, and GIS was measured in NIS openness using a proposed measurement framework. We were able to confirm a substantial increase in the overall average for NIS openness, representing the tangibility of the GIS perspective.

For our research questions, the first question may be answered as follows: "by understanding the GIS perspective as the openness and the expansion of the national innovation systems perspective, based on eight indicators under three types of innovation proposed in this paper, GIS indicators were able to be measured successfully". The second question can be answered as follows: "we have identified that due to globalization, the gradual expansion of NIS led to GIS, and it is the global innovation systems perspective which should be considered as a new sibling of the innovation systems perspective". We have also verified that when NIS openness is compared with NIS performance, there is a meaningful correlation with a large group of countries. Other countries in groups two and three, however, showed irrelevance between NIS openness and performance, thus providing insights for planning strategies to achieve better NIS performance or openness. This classification may be employed for further research by adding countries that were not included in this particular batch.

There is a list of implications from this research. First, considering the ongoing globalization and the emerging Global Grand challenges, it is predicted that the global innovation systems perspective will be accelerated. Since the SDGs were set, the concept of "sustainability" was spread beyond disciplines. The field of science policy and innovation studies was no exception. Innovation Policy Framework 3.0 was introduced, and norms such as responding to the Global Grand challenges were imposed [11,12]. Global challenges, also known as challenges faced by humanity, can only be solved by joint global responses, meaning that the world's cooperation is essential. Second, it is expected that when national governments and international organizations set innovation-related policies, they will adopt the GIS perspective. This will provide STI policies to consider the GIS perspective level, scale, and scope instead of an established NIS perspective. Nonetheless, this does not mean that the NIS perspective is less meaningful. It is essential to understand that one of the main purposes of this research is to suggest the GIS perspective as the new basis for the innovation systems perspective.

Although this paper attempted to explore the possibility of the GIS perspective, sophisticated analysis was limited as the GIS perspective is rather vague, as the main context of each countries varies and the institutions are still under national boundaries. Therfore, this study should rather be considered as a normative approach. Also, we believe that further analysis of the innovation systems perspective could be conducted beyond national boundaries.

Author Contributions: Supervision, S.P.; writing—original draft, A.C. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by the Science and Technology Policy Graduate Program of the Korea Institute of Human Resources Development in Science and Technology.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

[1] Available online: https://www.bloomberg.com/news/articles/2018-01-22/south-korea-tops-global-innovation-ranking-again-as-u-s-falls (accessed on 11 June 2021).

References

1. Balzat, M.; Hanusch, H. Horst. Recent trends in the research on national innovation systems. *J. Evol. Econ.* **2004**, *14*, 197–210.
2. Sharif, N. Emergence and development of the National Innovation Systems concept. *Res. Policy* **2006**, *35*, 745–766.
3. Martin, B.R. Twenty challenges for innovation studies. *Sci. Public Policy* **2016**, *43*, 432–450.
4. Niosi, J.; Bellon, B. The global interdependence of national innovation systems: Evidence, limits, and implications. *Technol. Soc.* **1994**, *16*, 173–197.
5. Archibugi, D.; Iammarino, S. The policy implications of the globalisation of innovation. *Res. Policy* **1999**, *28*, 317–336.
6. Carlsson, B. Internationalization of innovation systems: A survey of the literature. *Res. Policy* **2006**, *35*, 56–67.
7. Binz, C.; Truffer, B. Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. *Res. Policy* **2017**, *46*, 1284–1298.
8. Binz, C.; Truffer, B. The governance of global innovation systems: Putting knowledge in context. In *Knowledge for Governance*; Springer Publishers: New York, NY, USA, 2020; pp. 397–414.
9. Lee, S.; Lee, H.; Lee, C. Open innovation at the national level: Towards a global innovation system. *Technol. Forecast. Soc. Chang.* **2020**, *151*, 119842.
10. Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business Press: Cambridge, MA, USA, 2003.
11. Mazzucato, M. Mission-oriented innovation policies: Challenges and opportunities. *Ind. Corp. Chang.* **2018**, *27*, 803–815.
12. Schot, J.; Steinmueller, W.E. *Framing Innovation Policy for Transformative Change: Innovation Policy 3.0*; (Working Paper); SPRU Working Paper Series: Brighton, UK, 2016.
13. Freeman, C. Technological infrastructure and international competitiveness. In *OECD Ad hoc-Group on Science, Technology and Competitiveness*; OECD: Rio de Janeiro, Brazil, 1982.
14. Freeman, C. *Technology Policy and Economic Performance: Lessons from Japan*; Pinter Publishers: London, UK, 1987.
15. Lundvall, B.Å. *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*; Printer Publishers: London, UK, 1992.
16. Nelson, R. *National Innovation Systems: A Comparative Analysis*; Oxford University Press: New York, NY, USA; Oxford, UK, 1993.
17. Patel, P.; Pavitt, K. National innovation systems: Why they are important, and how they might be measured and compared. *Econ. Inno. New Technol.* **1994**, *3*, 77–95.
18. Metcalfe, S. The economic foundations of technology policy: Equilibrium and evolutionary perspectives. In *Handbook of the Economics of Innovation and Technological Change*; Blackwell Publishers: Oxford, UK; Cambridge, MA, USA, 1995.
19. Lundvall, B.Å. National innovation systems—Analytical concept and development tool. *Ind. Innov.* **2007**, *14*, 95–119.
20. Cooke, P.; Uranga, M.G.; Etxebarria, G. Regional innovation systems: Institutional and organisational dimensions. *Res. Policy* **1997**, *26*, 475–491.
21. Malerba, F. Sectoral systems of innovation and production. *Res. Policy* **2002**, *31*, 247–264.
22. Albert, M. *The System of Innovation Approach*; Paper Presented at the Meeting; Society for the Social Studies of Science: Cambridge, MA, USA, 2001.
23. Chesbrough, H. *Open Business Models: How to Thrive in the New Innovation Landscape*; Harvard Business Press: Cambridge, MA, USA, 2006.
24. Chesbrough, H. Business model innovation: It's not just about technology anymore. *Strategy. Leadersh.* **2007**, *35*, 12–17.
25. Brant, J.; Lohse, S. *The Open Innovation Model*; Research Paper; ICC (International Chamber of Commerce) Innovation and Intellectual Property Research Paper: Paris, France, 2014.
26. Patra, S.K.; Krishna, V.V. Globalization of R&D and open innovation: Linkages of foreign R&D centers in India. *J. Open Innov. Technol. Mark. Complex.* **2015**, *1*, 7.
27. Huizingh, E.K. Open innovation: State of the art and future perspectives. *Technovation* **2011**, *31*, 2–9.
28. Im, B.; Lee, K. From Catching Up to Convergence of the Latecomer Firms: Comparing Behavior and Innovation Systems of Firms in Korea and the US. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 191.
29. Kodama, F.; Shibata, T. Demand articulation in the open-innovation paradigm. *J. Open Innov. Technol. Mark. Complex.* **2015**, *1*, 2.
30. Park, H.S. Technology convergence, open innovation, and dynamic economy. *J. Open Innov. Technol. Mark. Complex.* **2017**, *3*, 24.
31. Dubickis, M.; Gaile-Sarkane, E. Transfer of know-how based on learning outcomes for development of open innovation. *J. Open Innov. Technol. Mark. Complex.* **2017**, *3*, 4.
32. Van de Vrande, V.; de Jong, J.P.; Vanhaverbeke, W.; de Rochemont, M. Open innovation in SMEs: Trends, motives and management challenges. *Technovation* **2009**, *29*, 423–437.
33. Lopes, A.P.V.B.V.; de Carvalho, M.M. Evolution of the open innovation paradigm: Towards a contingent conceptual model. *Technol. Forecast. Soc. Chang.* **2018**, *132*, 284–298.
34. Dahlander, L.; Gann, D.M. How open is innovation? *Res. Policy* **2010**, *39*, 699–709.
35. Lichtenthaler, U. Open innovation: Past research, current debates, and future directions. *Acad. Manag. Perspect.* **2011**, *25*, 75–93.

36. Fromhold-Eisebith, M. Bridging scales in innovation policies: How to link regional, national and international innovation systems. *Eur. Plan. Stud.* **2007**, *15*, 217–233.
37. Hipp, A.; Binz, C. Firm survival in complex value chains and global innovation systems: Evidence from solar photovoltaics. *Res. Policy* **2020**, *49*, 103876.
38. Tsouri, M.; Hanson, J.; Normann, H.E. Does participation in knowledge networks facilitate market access in global innovation systems? The case of offshore wind. *Res. Policy* **2021**, *50*, 104227.
39. OECD. International Co-Operation in Patents. Available online: https://stats.oecd.org/Index.aspx?DataSetCode=PATS_COOP (accessed on 2 March 2021).
40. OECD. DAC and CRS Code Lists. Available online: https://www.oecd.org/development/financing-sustainable-development/development-finance-standards/dacandcrscodelists.htm (accessed on 2 March 2021).
41. World Bank. Metadata Glossary. Available online: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/BX.GSR.ROYL.CD (accessed on 3 March 2021).
42. European Commission. EIS 2020 Methodology Report. 2020. Available online: https://ec.europa.eu/docsroom/documents/41861 (accessed on 27 May 2021).
43. DiMaggio, P.J.; Powell, W.W. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *Am. Sociol. Rev.* **1983**, *48*, 147–160.
44. Henriques, L.; Larédo, P. Policy-making in science policy: The 'OECD model' unveiled. *Res. Policy* **2013**, *42*, 801–816.
45. Sakbani, M. *A Re-Examination of the Architecture of the International Economic System in a Global Setting: Issues and Proposals*; Working Paper; UNCTAD: Geneva, Switzerland, 2006.
46. Mowery, D.C.; Sampat, B.N. The Bayh-Dole Act of 1980 and university–industry technology transfer: A model for other OECD governments? *J. Technol. Transf.* **2004**, *30*, 115–127.
47. Siepmann, T.J. The global exportation of the U.S. Bayh-Dole Act. *U. Dayton L. Rev.* **2004**, *30*, 209.
48. Grimaldi, R.; Kenney, M.; Siegel, D.S.; Wright, M. 30 years after Bayh–Dole: Reassessing academic entrepreneurship. *Res. Policy* **2011**, *40*, 1045–1057.
49. Lemola, T. Convergence of national science and technology policies: The case of Finland. *Res. Policy* **2002**, *31*, 1481–1490.
50. Martin, B.R. The evolution of science policy and innovation studies. *Res. Policy* **2012**, *41*, 1219–1239.
51. Freeman, C.; Perez, C. Structural crises of adjustment, business cycles and investment behaviour. In *Technical Change and Economic Theory*; Printer Publishers: London, UK, 1988.