Innovation Capacity in Developing Countries

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Innovation is an intrinsic capacity of humankind, enabling the adaptation to changes and managing probable solutions to problems regarding its welfare or its surroundings. It constitutes a key driver of sustainable growth. Moreover, innovation capacity is among the dynamic capacities leading to achieving a competitive and sustainable advantage. Hence, by adopting innovative and R&D practices, a country might enhance its growth and competitiveness, particularly for a developing country. In addition, it encompasses diverse perspectives, e.g., organizational capacity, public capacity, regional capacity, national capacity, among others. Therefore, many public and private organizations have focused their efforts on identifying and quantifying the variables that determine the innovation capacity of a country. Various mechanisms have been proposed to assess this capacity, such as the national innovation capacity, Global Innovation Index (GII), Global Competitive Index (GCI) , or European Innovation Scoreboard (EIS). These mechanisms aim at providing an objective measurement of the performance of a country regarding innovation capacity or innovation as a means to competitiveness. Each one of these presents a particular set of determinants, methods, and interpretations to assess innovation.

innovation capacity | innovation determinants | interpretive structural modelling (ISM)

1. Introduction

Several studies have analyzed the role, impact, and performance of several determinants of innovation capacity [1][2][3][4][5][6][7][8][9][10][11]. However, the studies in this field are highly dispersed, and only a few of them consider a prominent set of determinants [3][12][13][14][15]. In addition, when designing policies and actions to promote innovation and R&D, it may become overwhelming to include every determinant proposed in the literature and diverse entities, especially for a developing country dealing with various lacks and limitations. Thus, the main purpose of this research is to identify and analyze the relations between the key innovation determinants related to the innovation capacity of a country, regarding a developing country perspective, represented by the experts consulted for this work. To achieve this purpose, an interpretive structural modeling (ISM) approach is conducted as a qualitive method to determine the contextual linkages between the identified key determinants to further develop a contextual hierarchy of them and provide a better understanding of their impact on the innovation capacity of a country. With this in mind, this research addresses the need of clarifying the following research question: which are the key determinants affecting the development of innovation capacity in a country and how are they correlated to each other? This research endeavors to contribute to both the academy and practitioners by proposing a systematized roadmap to develop innovation capacity.

2. General Analysis of Innovation Capacity in Developing Countries

The capacity of a nation to innovate is defined as “the ability of a country—as both a political and economic entity—to produce and commercialize a flow of new-to-the-world technologies over the long term. National innovative capacity is not the realized level of innovative output per se but reflects more fundamental determinants of the innovation process” [16] (p. 900). Several agents and factors, including policymakers, industry decision-makers, researchers, governments, universities, legal frameworks, financing sources for R&D, and openness to international trade and investment, among others, fashion the complexity of innovation systems of a country [2][13][17]. Furthermore, countries reflect different degrees of innovation capacity as products of “economic geography” and “cross-country innovation policy” variations [16][18][19][20].

Due to the complexity of innovation systems, it is an intricate process to assess the capacity of a nation to be innovative. Hence, various organizations and scholars propose mechanisms to evaluate this capacity. Three main mechanisms are included in the present research. First, Furman et al. [16] introduced a framework to measure national innovation capacity (NIC). The authors proposed a mathematical model applicable to member countries, which estimates national innovative productivity based on the analysis of multiple variables taken from various sources (e.g., OECD’s database, US Patent and Trademark Office (USPTO), and International Institute for Management Development (IIMD)). The model systematizes the variables into four groups: quality of the common innovation infrastructure, cluster-specific innovation environment, the quality of linkages between the two aforementioned, as well as contributing and related outcomes factors.

Second, the World Intellectual Property Organization (WIPO) published the first edition of the Global Innovation Index (GII) in partnership with Cornell University and INSEAD in 2007 [20][21]. The latest edition of GII, published in 2021, includes two sub-indexes, which, in turn, group seven pillars [19]. The first sub-index, Innovation Input Sub-Index, comprises the pillars of institutions, human capital and research, infrastructure, market sophistication, and business sophistication. The second, Innovation Output Sub-Index, groups the pillars of knowledge and technology outputs, and creative outputs.

Third, the World Economic Forum presented the Global Competitiveness Index (GCI) [22] in 2004, with a focus to “[identify] and [evaluate] the factors that underpin the process of economic growth and human development” [23] (p. 8). GCI 4.0, its latest version, ranks countries’ competitiveness considering 98 indicators, where 64 are new in relation to the previous version [24]. These indicators are organized into twelve pillars grouped in four categories. Enabling environment assesses four pillars: institutions, infrastructure, ICT adoption, and macroeconomics stability. Human capital includes health and skills. The category of markets evaluates product market, labor market, financial system, and market size. Innovation system, the last category, comprises the pillars of business dynamism and innovation capacity. This last pillar qualifies and quantifies the capacity of a country’s environment to encourage creativity, connectivity and collaboration, the formal research and development, and its ability to transform ideas into new products and services.

For the purpose of this research, a systematic literature review was conducted to analyze fourteen innovation determinants [25]. These determinants are the result of comparing NIC, GII, and GCI 4.0 (mainly considering the 12th pillar, innovation capacity). The determinants included correspond to the intersections between the three indexes [26]. **Table 1** presents the description of the determinants included in this research.

Table 1. Innovation determinants based on NIC, GII, and GCI 4.0.

Code	Indicator	Description	References
D1	Openness	Corresponds to the impact of international trade (e.g., high-tech exports, ICT imports) and investment (e.g., FDI, venture capital, market capitalization) on the innovation capacity of a country. This includes the extent to which regulations, policy, and tariffs stimulate, facilitate, or prevent international trade or investment from affecting the R&D in a country.	[4][8][16][19][27][28][29][30][31][32][33][34][35][36][37]
D2	GERD private industry	Refers to R&D expenditures funded and performed by private industry and businesses.	[1][6][7][16][18][19][38][39][40][41][42][43][44][45][46][47][48][49]
D3	Full-time R&D personnel	Refers to the full-time R&D engineers, scientists, and professionals engaged in the creation and conception of new knowledge in all sectors. R&D professionals develop, enhance, and research theories, models, methodologies, software, instrumentation, or operational techniques.	[12][16][19][33][36][46][50][51][52][53][54][55][56][57][58][59][60][61][62]
D4	Promotion & protection for innovation/IP	Alludes to the strength and extent to which a country promotes and protects intellectual property (IP). This includes the policy framework promoting and protecting IP rights, as well as innovation.	[16][23][30][44][63][64][65]
D5	R&D performed by universities	Includes all expenditures funded and performed by universities to R&D activities.	[6][7][16][39][45][66][67][68]
D6	Utility models	Refers to a special form of patent right. To grant a utility model, there are slightly different conditions and terms from those for regular patents. The terms include a briefer period for protection and less rigid patentability requirements.	[19][27][30][58][65][69]
D7	Gross expenditure on R&D	Consists of both public and private capital and current expenses for R&D work performed systematically to advance knowledge and its usage for new applications. Hence, GERD refers to the “total domestic intramural expenditure on R&D during a given period as a percentage of GDP”. “Intramural R&D expenditure” is all expenditure for R&D funded within a sector of the economy or statistical unit during a particular period, without considering the source of funding [19] (p. 186).	[1][4][7][16][19][30][31][33][36][45][49][54][68][70][71]

Code	Indicator	Description	References
D8	Multi-stakeholder R&D collaboration	Refers to the extent to which universities and businesses perform R&D activities in collaboration. Includes the sharing efforts to develop new ideas, models, concepts, theories, and methods.	[1][2][6][11][12][19][23][33][41][45][46][48][53][62][66][72][73][74][75][76][77][78][79]
D9	Expenditure on education	Corresponds to all the share of GDP expenditure on higher education, including secondary and tertiary education. It comprises spending financed from abroad sources to the government.	[4][16][19][32][49][80][81][82]
D10	University/research institution prominence	Refers to the standing and prominence of public and private research institutes, universities, corporative entities, and government agencies.	[14][19][23][72][83][84][85][86][87]
D11	State of cluster development	Alludes to the extent to which innovation clusters are widespread. It includes the degree of development and deep clusters (i.e., geographic concentration of producers of services and products, suppliers, firms, and institutions in a specialized field). Moreover, considers the relationship between government, industry, and universities to enhance innovation and creativity.	[3][6][7][17][19][23][38][41][47][48][50][55][56][62][72][73][74][75][79][88][89][90]
D12	Co-inventions	Refers to the patent family applications with co-creators located overseas.	[7][10][19][23][41][53][56][72][89][91][92]
D13	Scientific and technical patents/articles	Includes patents and citation of patents registered by the industry or universities, as well as in collaboration between them both. It also includes citations of patents in scientific articles.	[6][7][19][23][33][41][53][58][66][69][72][73][74][77][88][93][94]
D14	Trademarks applications	Owners of particular products or providers of particular services create a sign to distinguish their products and/or services from those of the competition. A trademark may include images, names, logos, slogans, figures, words, numbers, moving images, and sounds, which can stand by themselves or in combination. To register a trademark, owners are subject to the procedures and legislation of regional and national IP offices. The rights of a trademark are limited to the IP office jurisdiction where it was registered. To register a trademark, the owner can file an international application through the Madrid System or at the national or regional office.	[19][23][34][63][95]

[4][16][19][32][33] [32] … nt on the … ernational … vers, and … l level of … nd export

specialization) and domestic orientation (i.e., education, financial inclusion, and control of corruption). Through an exploratory analysis with a sample of 39 African countries, the authors found that low-income countries enhance their national level of innovation by adopting an international orientation, while relatively higher-income countries with a domestic orientation have a higher national level of innovation. Furthermore, in a study conducted by Adikari et al. [4] in Sri Lanka, the authors concluded that, although a firm should locally focus their efforts on development and research to build innovation capacities, the main motivation for attracting foreign direct investment by firms in developing countries should be to obtain advanced technology.

Sourcing the founding for R&D is also a key determinant to develop innovation capacity. Innovation may result among the expensive undertakings, although necessary, to compete in a highly dynamic environment. Moreover, “expenditure on R&D reflects the nation’s absorptive capacity and represents innovation efforts” [4] (p. 6). Different public (i.e., governments) and private entities constitute the source to found the expenditures on innovation and R&D [27][31][42][70][96]. Private industry is largely responsible for providing the financial resources for disruptive innovation [42]. Choi et al. [8] studied, from a system dynamics approach, a sequence of feedback causal linkages where R&D investments generate exchanges between entities of technological innovation, new knowledge stocks, and enhancing “technological knowledge triggers”, driving the firm profits through the process of commercialization. R&D investments generate R&D knowledge regarding new products, which improves market performance by introducing innovate products. This may be seen as a direct and positive impact of R&D investment on performance. One of the authors’ findings is that an intensive investment strategy for product innovation has a higher positive effect long-term on a firm’s revenue than a process-innovation-intensive strategy. They conclude that a firm should offer innovative products, fulfilling the needs of their customers as a means to achieve a competitive advantage.

Research institutes, universities, and firms need skilled personnel to perform innovation and R&D activities, leading to effective innovative results, such as innovative new products, processes, patents, trademarks, among others [16][51][97]. Full-time R&D personnel should focus their efforts on actively producing new innovative ideas and introducing performance measures and innovation targets into daily operations. It is necessary to properly train and allocate R&D personnel to support innovation and R&D activities [40][98]. The firm requires to invest in its human capital. Its personnel need to support and manage R&D in-house as well as outsiders, such as universities and research centers, to enhance innovation systems [51][99]. Thus, the collaboration of the personnel with external pairs will improve benchmarking opportunities and provide cost advantages [62].

Innovation is a risky and proactive undertaking. Its achievement provides a competitive advantage for the firm, as well as for the country hosting such an undertaking. It demands human capital, financial sourcing, and technology, among other elements, to endeavor. Hence, it is important to provide the proper promotion and protection of innovation and R&D activities. Holmes et al. [100] conducted an empirical study to identify the factors affecting foreign firms on their decision to establish R&D centers in China. The authors noted that, on this decision, the host country and the foreign firm benefit. Their research found that industry investment, IP protection, and target industry growth have a significant impact on the decision of foreign firms when considering to establish a new R&D center in China. Strong IP protection and high industry growth play a positive role in attracting foreign R&D investment. Furthermore, the authors found that the level of IP protection bends the effect of industry innovation investment, i.e., higher levels of protection have a positive impact on foreign R&D investment and vice versa. Similar findings point to the importance of promoting and protecting innovation and R&D undertakings as a means to enhance innovation capacity [44][47][64].

A large amount of innovation and R&D projects are performed by universities but funded by an external entity due to the capacity to collaborate with the private industry, governments, etc. [7][66][77][93]. Fabrizi et al. [33] analyzed the difference regarding the impact of EU-funded framework programs on the generation of new knowledge (patents) across public research centers, universities, and private firms. The authors found that all of these entities benefit from joint projects with this form of external investment. However, the findings showed that, while the private firms benefit less, most of this benefit goes to public research centers and universities. Further evidence also showed the importance of participating in international research projects and including international innovation researchers to enhance the absorptive capacity to maximize the benefit from cooperating in international R&D projects.

Utility models are a special form of patent right for inventions [101]. Likewise, to patents, they protect the intellectual property for a limited period of time. However, utility models have a different scope. Patents involve non-obviousness, invention, and novelty. Utility models may oversee inventiveness. Hence, while the process to register a patent is expensive and exhaustive, the process to grant a utility model is more flexible and affordable. However, they enhance the performance of a firm by promoting technical learning on the way to achieving a patentable innovation. Hence, many countries, particularly developing countries, consider utility models as an accessible path to innovation [27][65][69][102].

Human capital is a critical factor for innovation and economic growth [81]. Education and its efficient allocation drive the development of human capital. Hence, the expenditure on education is a key indicator of human capital development [4][82]. Education expenditure should be oriented to train skilled personnel to perform diverse tasks according to the requirements of a firm or a country [6].

Multi-stakeholder R&D collaboration plays a key role in developing innovation capacity. Particularly, the key role of university–industry collaboration on driving innovation capacity and economic growth is largely recognized [7][18][71]. A particular contribution of this close collaboration is the benefit of knowledge and technology transfer [41][58][66][77], encouraging multi-disciplinary research projects [7][72][76]. As the relationship between universities, industries, and other entities within an innovation system becomes stronger, the participants in the system engage in further formal linkages, shorten the geographical distance, and develop further innovation mechanisms, enhancing the state of the innovation cluster [41][58][72][73][76][89]. The innovative synergy performed by these clusters contributes to strength innovation systems and plays a key role in knowledge management [66].

University/research institution prominence depends on the quality of academic research, patent expenditure, composition of the academic staff, international orientation, student ratio, and employer reputation [19][23][103][104]. Prominence also refers to the relevance of the institution in a given research area. This has a positive impact when engaging in research collaborations, as well as on achieving co-inventions, co-publications, and scientific absorptive capacity [41][72][79][83].

Co-inventions and co-creations are the result of collaborative R&D efforts among multiple stakeholders sharing innovative goals [7][41][72][79]. Hence, the state of the cluster and the prominence of the collaborative ties have a positive impact on the value co-creation processes that achieve innovation results [41][91][92][105]. This is particularly significant in developing countries to cope with limited resources [27][65]. Hence, it is important to develop adequate strategies to effectively choose partners to achieve the desire innovation goal and gain a mutual benefit [56][77].

Scientific and technical patents and articles, including citations of patents, are largely considered as a measure of innovation capacity [1][12][16][27][65]. The quality of patenting is the result of effective collaboration between industry, university, and/or research institutes [7]. It also depends on the access to financial support to sustain the R&D process related to developing a patent [11][41][66]. Hence, the state of the cluster has a significant impact on the knowledge structure necessary to develop the patent landscape and patent portfolios [6][94].

Finally, trademark applications are related to IP rights. Entities invest in developing a brand, image, and message to be identified by the market in a unique way [63]. It requires innovative and creative capacities to create an attractive and effective trademark [106]. Hence, a fitting innovation system is necessary to stimulate the development and protection of such efforts and investment in mark creation and the commercialization of new inventions [34][63][95]. In addition, value creation is related to the capacity of managing and marketing technology patents [63] as a means to develop dynamic capabilities and capacities to create a competitive innovative advantage [107][108][109].

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