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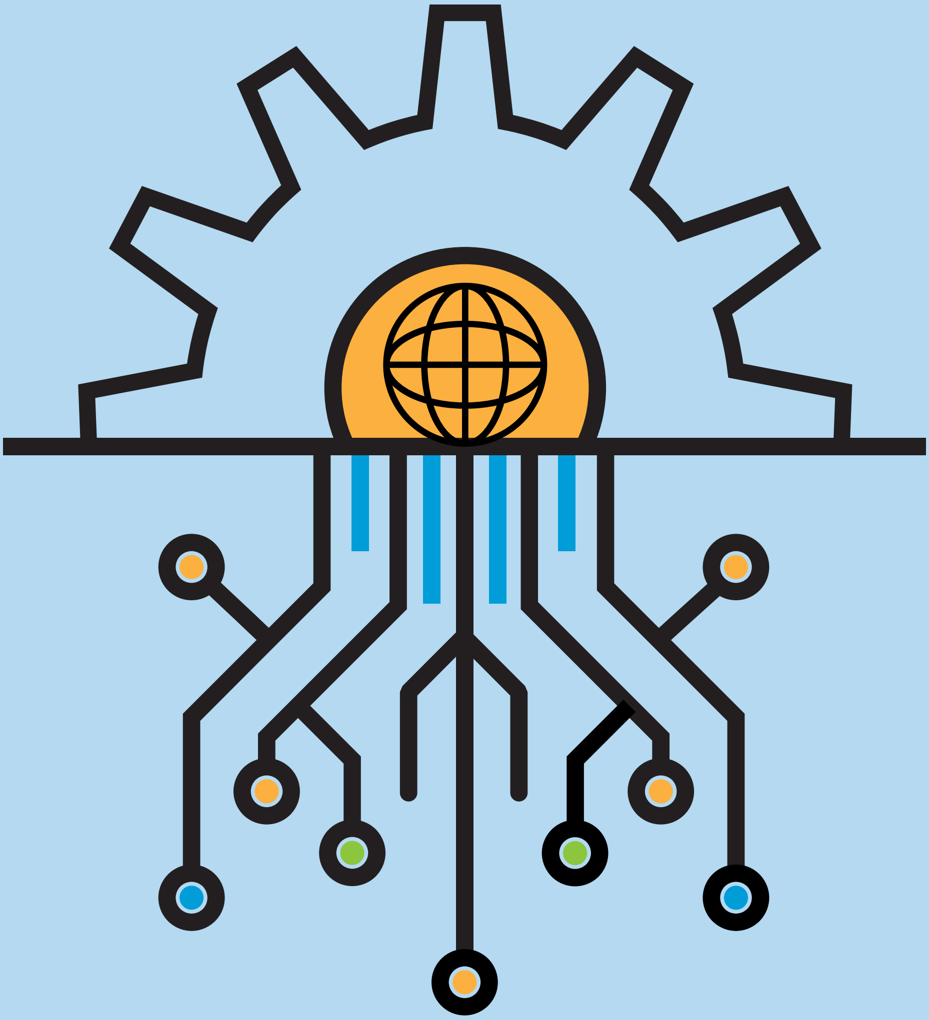

Analyzing the Landscape of Industrial Innovation in Developing Countries

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Abbreviations

CDMA: Code-Division Multiple Access

EQuIP: Enhancing the quality of industrial policy

GERD: Gross expenditure on R&D

HI: High income

ICT: Information and communication technology

IPR: Intellectual property rights

ISO: International Organization for Standardization

LI: Low income

LMI: Lower-middle income

MLP: Multi-level perspective

NSF: National Science Foundation

NSI: National systems of innovation

ODM: Original design manufacturer

OEM: Original equipment manufacturer

R&D: Research and development

RoK: Republic of Korea

SI: Systems of innovation

SDGs: Sustainable Development Goals

STI: Science, technology and innovation

UMI: Upper-middle income

WIPO: World Intellectual Property Organization

1 Definition, objectives and description of the tool

The tool presented in this document offers guidance for policymakers, especially in developing countries, interested in better integrating the promotion of industrial innovation as part of their industrialization efforts. The tool addresses questions such as how to assess the state of play of industrial innovation in a country, the relevant policy issues related to the promotion of industrial innovation, and how to fit all of them together in comprehensive industrial development strategies (Gault 2010).

Consistent with current understanding of innovation as both a systemic and systematic activity (Box 1), a key assumption of this tool is that a systems of innovation (SI) approach is suitable to address the complexity of challenges that can arise in a country's quest to foster industrial innovation as a driver of industrialization. For example, efforts to fix market failures to invest in innovation will be fruitless if public funding does not deliver appropriate institutional arrangements to protect outcomes from such investments. Suboptimal private-sector investment in innovation is the consequence of information asymmetries and knowledge spillovers. Desirable solutions to these gaps span several areas, including but not limited to funding, and need to be conceived of and approached through systemic perspectives. How? By increasing technological capabilities of firms to better grasp emerging technological opportunities, facilitating knowledge exchanges and information-sharing among specialized entities or between knowledge producers and knowledge users in the innovation process; or by strengthening knowledge appropriability regimes to foster incentives to innovate, while enabling a larger number of actors to engage in innovation.

Box 1. Innovation: A systemic and systematic process

Modern theories of innovation explain this activity as both a systemic and systematic activity. Innovation is *systemic* in the sense that it emerges from an interactive process where knowledge exchanges take place among different knowledge producers and knowledge users (Chris Freeman 1995; Lundvall 1992).

Innovation is also a *systematic* activity in that it requires consistent commitment of resources and efforts to support knowledge creation, mobilization and use to underpin innovation over a long period of time.

The systemic and systematic nature of innovation also implies continuous learning and capability-building processes, aligned with the evolving nature of the actors that carry out innovation and their relationships within a given system of innovation. Moreover, heterogeneous environmental factors, both internal and external to a particular innovation system, imply that innovation is a path-dependent activity that results from specific contexts, history and strategic challenges that each innovation system faces and from the approaches implemented to solve problems over time.

The systems of innovation (SI) framework deals with the systemic nature of innovation by factoring out the roles of diverse actors (e.g. universities, governments and intermediaries as well as firms) in the innovation process as well a their interactions and networking under the broad contexts of underlying and enabling institutions (Edquist & Hommen, 1999; Lundvall, 2010).

Source: Authors' elaboration.

At the same time, it is acknowledged that if a systems of innovation (SI) framework is applied to the industrial upgrading of developing countries, it needs to be adjusted to their realities. For instance, all relevant actors in the system are not in place in many developing countries and, even if they are, their capacity to design and implement necessary policy is limited. Therefore, the notions of learning and capability-building become fundamental in the context of developing countries. In this regard, failures in a system are more pronounced in developing countries and the use of notions that have emerged in the system transformation literature such as reflexivity, directionality and demand articulation as key concepts will be retained from this tool.

The structure of this tool is as follows. First, we provide a description of, meaning of and rationale for the indicators drawing on the System Failure Framework proposed by Weber and Rohracher (2012). Second, we construct a methodology for the tool that includes rationale, definition and calculation, and data sources and coverage of the indicator system. Under the indicator system, we explore in more detail the real-world contexts of 20 selected countries (15 developing countries and five developed countries) as examples using quantitative and qualitative policy data. Third, we show the comparative performances of these 20 selected countries using a heatmap dashboard (see Figure 63) and ways to identify performance gaps of a country within the indicator system. Fourth, we discuss how the tool and its indicators fit in the policymaking and implementation processes within developing countries.

2 Description, meaning and rationale of indicators

2.1 Systems of innovation: An overview

Innovation and industrial development are closely intertwined; they are powerful drivers of economic diversification and value addition, economic growth and sustainable development (United Nations 2015). Innovation contributes to a continuous process of improving and making more affordable existing goods and services, while sustaining a steady flow of goods and services that enable increased prosperity (Freeman and Soete 1997). Innovation and industrial development can also support the achievement of the UN Sustainable Development Goals (SDGs) by balancing socioeconomic and environmental development objectives (UNIDO 2019; 2016).

Today, policy formulation in developing countries confronts a *twin challenge*: one, country-specific and the other, universal. The country-specific challenges are to answer the questions related to how and in which order to develop specific sectors or innovation inputs (e.g. human resources, knowledge and technology assets, technological infrastructure, or the amount, timing and targets of funding) that might fit best with the circumstances and development goals the country faces. The challenges, then, appear in many different forms, such as how to increase production scale, productivity and efficiency to achieve development goals, taking into account multiple megatrends shaping the future of manufacturing and innovation, such as digitalization and restructuring of global value chains, among others (UNIDO 2019; 2021). The other challenges, applicable to all countries, require answering the question of how to conform to global challenges around sustainability, inclusiveness and, as the ongoing COVID-19 pandemic demonstrates, resilience against emerging disasters, with major implications for socioeconomic activities and the environment (Aiginger and Rodrik 2020; Ferrannini et al. 2021; UNIDO 2021).

SI perspectives emphasize the importance of actors (and their capabilities and learning), institutions and networks. Actors include knowledge and technology producers, such as universities and research institutes, firms and other relevant players such as knowledge brokers, interest groups, users and even the general public (Geels 2004). Institutions include laws, regulations and policies relevant to innovation and industry development. Networks are both formal and informal linkages among various actors. Without the effective alignment of these three components with economic and innovation activities, the overall performance of the innovation systems would hardly reach expected levels even if market failures are minimized. Weber and Rohracher (2012) also regarded infrastructure failure to be as crucial as the failures in these three structural components. In addition, Weber and Rohracher (2012) add transformation system failures as crucial determinants for the functioning of innovation systems, listing in particular failures in directionality, demand articulation, policy coordination and reflexivity in transforming innovation systems. Hence, innovation systems underperform when markets fail,[1] structural components are ill prepared, or when transforming the system is not effective nor timely. Innovation system failures fall into one of 12 distinct categories (Table 1).

Table 1. Categories of system failures

TYPE	FAILURE	FAILURE MECHANISM
Market failures	Information asymmetries	Uncertainty about outcomes and short time horizon of private investors lead to undersupply of funding for research & development (R&D).
	Knowledge spillover	Public good character of knowledge and leakage of knowledge lead to socially sub-optimal investment in (basic) research and development.
	Externalization of costs	The possibility to externalize costs leads to innovations that can damage the environment or other social agents.
	Over-exploitation of "commons"	Public resources are over-used in the absence of institutional rules that limit their exploitation (tragedy of the commons).
Structural system failures	Infrastructural failure	Lack of physical and knowledge infrastructures due to large-scale, long-time horizon of operation and, ultimately, too-low return on investment for private investors.
	Institutional failures	Hard institutional failure: Absence, excess or shortcomings of formal institutions such as laws, regulations and standards (in particular regarding intellectual property rights [IPR] and investment) create an unfavourable environment for innovation. Soft institutional failure: Informal institutions (e.g. social norms and values, culture, entrepreneurial spirit, trust, risk-taking) that hinder innovation.
	Interaction or network failure	Strong network failure: Intensive cooperation in closely tied networks leads to lock-in into established trajectories and a lack of infusion of new ideas, due to too inward-looking behaviour, lack of weak ties to third actors and dependence on dominant partners. Weak network failure: too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning.
	Capabilities failure	Lack of appropriate competencies and resources at actor and firm level prevent the access to new knowledge and lead to an inability to adapt to changing circumstances, to open up novel opportunities, and to switch from an old to a new technological trajectory.

1 Markets fail when the outcomes or activities in the realm of innovation are subject to information asymmetries, knowledge spillovers, externalization of costs, or overexploitation of shared resources (the so-called "commons" problem).

Transformational system failures	Directionality failure	Lack of shared vision regarding the goal and direction of the transformation process; inability of collective coordination of distributed agents involved in shaping systemic change; insufficient regulation or standards to guide and consolidate the direction of change; lack of targeted funding for research, development and demonstration projects; and infrastructures to establish corridors of acceptable development paths.
	Demand articulation failure	Insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users; absence of orienting and stimulating signals from public demand; lack of demand-articulating competencies.
	Policy coordination failure	Lack of multi-level policy coordination across different systemic levels (e.g. regional–national–European or between technological and sectoral systems); lack of horizontal coordination between research, technology and innovation policies on the one hand and sectoral policies (e.g. transport, energy, agriculture) on the other; lack of vertical coordination between implementing agencies leads to a deviation between strategic intentions and operational implementation of policies; incoherence between public- and private-sector institutions; no temporal coordination, resulting in mismatches related to the timing of interventions by different actors.
	Reflexivity failure	Insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance; lack of distributed reflexive arrangements to connect different discursive spheres or to provide spaces for experimentation and learning; no adaptive policy portfolios to keep options open and deal with uncertainty.

Source: Authors' elaboration based on Weber and Rohracher (2012).

The National Systems of Innovation (NSI) framework enables policymakers to address many systemic components that the market failure rationale previously overlooked. Still, the NSI framework faces limitations in addressing dynamic changes in the systems themselves and discussing the normative nature of systems change (Carlsson et al. 2002; Geels 2004). For the NSI framework to facilitate a country's ability to achieve an instrumental goal such as economic development or innovation-driven industry development, it must provide concrete and normative guidance, at an operational level, on how, for example, policymakers can decide where to start an investment or which industry to focus more on than others. While the NSI framework has been useful to analyse the relative strength of system's components in a comparative setting, it still provides little insight into the transformation and directionality of innovation systems. In the context of developing countries, this becomes more pronounced. A frequent criticism of the NSI is the assumption that all relevant actors in the system are in place, which is not necessarily the case. Further, even if they are in place, their capacity to design and implement policy is limited. That's why issues of learning and capability-building become fundamental to addressing this criticism.

The introduction of a functional approach helps to address some of the limitations in the NSI framework. Both the functional approach of SI (Bergek et al. 2008; Hekkert et al. 2007) and the multi-level perspective (MLP) (Geels 2004) focus on the change process and dynamic transformation of innovation systems. Their focus goes beyond creating useful variations through innovation, as the market failures argument tends to gravitate. Rather, they expand the scope of interventions to changing the selection environment (Nelson and Winter 1982). Thus, government's role go beyond simply providing infrastructure or suitable institutional frameworks to encompass integrating "all public actions that influence or may influence innovation processes" to be *holistic* (Borrás and Edquist, 2019, p. 39). The same argument is also found in the recent literature on innovation catch-up as well. For example, Yap and Truffer (2019) emphasize, in catching up, the importance of mechanisms that can endogenize "windows of opportunity" through "the proactive interplay of strategies by different actors in shaping the potential future trajectories of upcoming socio-technical systems" (Yap and Truffer, 2019, p. 1033). This leads us to the roles that policy capability can play in helping policymakers understand and monitor the position and progress of a given innovation system—what is often called the *reflexivity* function (Box 2)—and in strategizing and direction-setting, commonly understood as policy *directionality* (Box 3). These notions of reflexivity and directionality are relevant to link development of policy capacity as part of efforts to mobilize science, technology and innovation (STI) for the achievement of the SDGs (UN-IATT and UNIDO, 2022). Effective strategies or directions can be successfully implemented if and only if they are supported with a proper policy mix and buttressed through a spontaneous selection environment of the market. This requires the proper functions of both policy coordination and demand articulation.

Box 2. Reflexive capability

Policymakers should develop the ability to identify and monitor what capabilities and resources are already in place and which ones are needed in order to achieve a determined development path. This, we call *reflexive capability*.

Regarding innovation policy specifically, the primary goal of reflexivity is to identify systemic problems in four structural components: **1) infrastructure, 2) institutions, 3) interactions, and 4) actors/capabilities.**

What is particularly important in mitigating reflexivity failure is the presence of a relevant think tank responsible for supplementing the lack of capacity of a government in developing countries to monitor, design and implement public-policy services.

Source: Authors' elaboration.

Box 3. Policy directionality

A starting point for a transformative system change entails addressing the difficult task of establishing a proper direction. The difficulty emerges from country heterogeneity, path dependence in development, and contextual changes over time. Generally, directionality is not just an outcome of imitating a successful precedent. For example, the Republic of Korea (RoK)'s bold initiative in developing the world's first Code-Division Multiple Access (CDMA) protocol in early 1990 was undoubtedly successful at the time but hardly imitable today. Each country must find its own development path.

Directionality thus provides the sense, orientation or guidance of searching for a given strategy or intended course of policy intervention. It builds on an adequate understanding of the innovation system to formulate a strategy and direction. This is related to directionality failure or guidance of search. Wieczorek and Hekkert (2012) present practical diagnostic questions that can be applied here as follows:

- **Is there a clearly articulated and shared goal for the system?**
- **Is it generic or specific?**
- **Is it supported by specific programmes, policies, who are the system's frontrunners?**
- **Is the objective inducing government activities?**
- **What are the technological expectations (negative/ positive)?**
- **Does the articulated vision fit in the existing legislation?**

Source: Authors' elaboration.

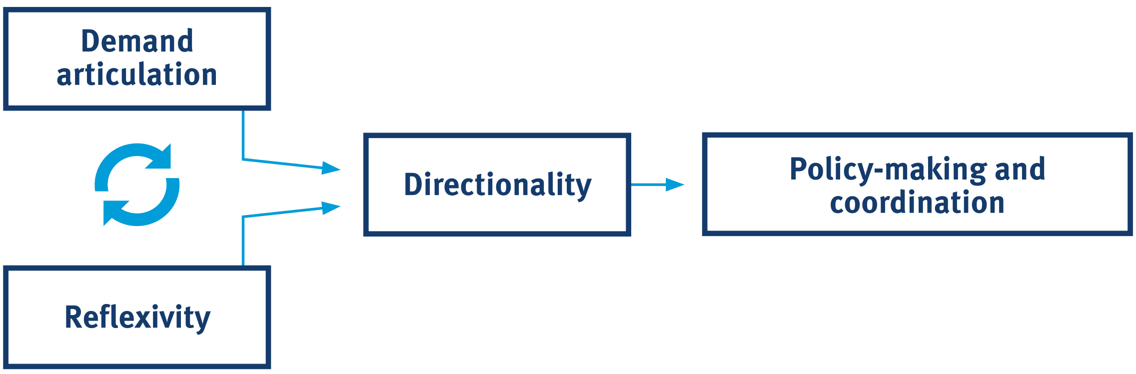
2.2 Policy diagnosis using the system failure framework

A basic approach to diagnosing innovation policy in developing countries is to walk through the list of system failures in Table 1, identifying which types of failures are prominent and, at the same time, that are easily fixable under the specific contexts of the country of interest. However, considering the myriad of attributes and elements characteristic of each system component,[2] it can easily become overwhelming to examine all those system components and their characteristics. An alternative approach is to focus on core elements. When faced with severe constraints in resources and capabilities, which many developing countries experience, policymakers will look for a way to effectively redirect resources to select areas of technologies, sectors, actors or regions. Any sustainable system must have the ability to self-correct and prioritize actions and resource allocation.

Figure 1 presents a schematic diagram of the process of transforming innovation systems. It is the analytical framework guiding the construction of the tool, the identification of indicators and subsequent analysis and interpretation. The main intended outcome of this tool is to assist policymakers interested in promoting innovation system transformation to achieve goal or set of goals. Governments are key actors in any innovation system, but they need capabilities and tools to assess their own performance. Hence, a mechanism like the tool presented in this report is highly pertinent in developing country governments' efforts to industrialize.

There are two foundational capabilities required for adequately setting a direction: *reflexivity* (Box 2) and *demand articulation* (Box 4). In a strategic management context, one needs to analyse contextual factors (such as policy, economic, social, technological, environmental and legal environments), industry factors, and internal capabilities to make a proper directional choice or strategy. Similarly, policymakers also need to assess the attractiveness of a particular technology or sector—analogous to *demand articulation,* as conceptualized by Weber and Rohracher (2012)—as well as the strength of the innovation system's components to make a proper development strategy, which is analogous to *reflexivity*.

Figure 1. Process for transforming an innovation system



Source: Authors' elaboration.

2 For example, actors include firms, universities, government organizations and agencies. Firms can be broken down into a number of industries, size classes, boundaries of activities, etc. Institutions also cover a variety of laws, regulations, policies and informal norms and customs. Infrastructure to be considered also spans widely over technological, financial and physical realms.

Box 4. Demand articulation

When taking into account demand articulation, the first step is to establish a workable definition of demand. However, this may seem nearly impossible in the context of a broad national system of innovation. An alternative is to focus on some attributes worth considering in developing and/or upgrading an innovation system aligned with a transformative development goal. The following question may guide the demand articulation process.

- ***Where will the demand come from: Public or private?***

Public demand generally provides more direct access to the hands of policymakers than private demand. For example, RoK has utilized public demand adeptly in developing high-speed rail systems, fully electronics telephone switching systems, and CDMA wireless protocol.

- ***What are the units of demand: product, process, service, industry or technology?***

Demands are multifold across different artifacts and material units. Broad scanning is recommended.

- ***How far in the future will demand be realized?***

The further in the future demand is expected to be realized, the more uncertainty and reluctance to invest. Therefore, when one's capability base is stringent, targeting near-future demand makes more sense.

- ***What will be the scale of demand?***

The scale of demand falls in a niche or mass-market category. It might be regional, national, global. Some are industry-specific and some others of general-purpose.

- ***How well will demand be articulated?***

Hands-on knowledge from market participants and users is crucial. Building participatory processes and forums is necessary. Foresight and forecasting capability are also crucial. Because of the high level of expertise needed to conduct these tasks, it is desirable to establish or partner with dedicated organizations, such as a research institute, to operationalize these functions.

Source: Authors' elaboration.

Directionality at the system level should be integrated into a set of policies to instigate actions around concrete systemic problems (Table 2). Policymaking processes, in general, muddle through a complex web of intellectual and social interactions among different stakeholders depending on the nature of the policy. Establishing a particular direction or issue as a policy agenda often requires massive efforts of policy entrepreneurs combined with efforts from the relevant stakeholders (Kingdon 1984). Developing viable policy alternatives also depends on numerous different factors, including policy ingenuity, proven policy models imported from other contexts, and social construction (Ahlqvist et al. 2012; Tuominen and Ahlqvist 2010). Selecting a prominent policy alternative is also subject to environmental factors as well as internal factors such as the social dynamics of stakeholders (Geels 2004; Jenkins-Smith et al. 2014; Markard et al. 2016). Collectively, this is understood as capability policymaking and coordination, partly following the Weber and Rohracher (2012) model.

Table 2. Goals of systemic instruments per (type of) systemic problem

SYSTEMIC PROBLEM	(TYPE OF) SYSTEMIC PROBLEM	GOAL OF SYSTEMIC INSTRUMENT
Actors' problems	Presence?	Stimulate and organize participation of relevant actors (1)
	Capabilities?	Create space for actors capability development (2)
Interaction problems	Presence?	Stimulate occurrence of interactions (3)
	Intensity?	Prevent too strong and too weak ties (4)
Institutional problems	Presence?	Secure presence of hard and soft institutions (5)
	Capacity?	Prevent too weak and too stringent institutions (6)
Infrastructural problems	Presence?	Stimulate physical, financial and knowledge infrastructure (7)
	Quality?	Ensure adequate quality of infrastructure (8)

Source: Authors' elaboration based on Wieczorek and Hekkert (2012).

Next, we discuss a set of indicators to help policymakers assess systemic problems that may affect performance of their relevant systems of innovation.

2.3 Indicator system

A proper set of indicators helps policymakers identify systemic problems in their STI systems as well as articulate demands for innovation. In line with the idea of evidence-based policymaking—the foundation of UNIDO's EQuIP—the indicator system proposed here aims to provide a foundational element of evidence-based policy-making, which remains absent or suboptimal in the case of many developing countries. There are widely used indicator systems in STI, such as the Science and Engineering Indicators from the United States' NSF (National Science Board & National Science Foundation, 2022), the Main Science and Technology Indicators from the OECD, and the Global Innovation Index from WIPO (WIPO 2021), to list just a few. They use well over hundreds of STI indicators, many of which, however, are often not available nor fit into the context of the developing countries.

To identify indicators that are generally available for most developing countries and, at the same time, are sufficiently informative of the developing country context, we apply three selection principles. First, indicators must be *publicly available* for a wide range of countries, including developing countries. Second, indicators should be *relevant* to STI and industrial policy, especially for developing countries. Third, if there are similar but somewhat different indicators that satisfy the first and the second principles, the selected indicator should be *representative and simple* enough for policymakers to readily understand its linkage to the real world.

The structure of our indicator system is presented in Table 3, and following Figure 1, begins with *reflexivity* and *demand articulation* as the two top-level components. Reflexivity is then broken down into the four pillars of innovation systems discussed in section 2: infrastructure, institutions, networks, and actors and capabilities. For demand articulation, most of the questions posed in Box 3 are not generally answerable using quantifiable statistics, especially for developing countries. Thus, we focus on three aspects: 1) the roles of the public sector, particularly as a consumer of innovation, including through strategic procurement of innovation; 2) the relative size of the digital industry in the import market; and 3) the relative size of sophisticated industries in the export market. Both 2 and 3 are used as a proxy for a government's intended policy efforts to promote industrially upgraded products in its domestic and exporting markets.

Table 3. Structure of the indicator system

SYSTEM COMPONENT			INDICATOR
LEVEL 1	LEVEL 2	LEVEL 3	
Reflexivity	Infrastructure	Physical	Electricity generation installed capacity (kW) per capita
		ICT	Fixed broadband subscriptions per 100 people
		Knowledge	Enrollment ratio in tertiary education
	Institution	R&D investment	Expenditure on R&D as % of GDP
		IPR protection	Patents by non-residents, per million people
		Business	New business registration per 1,000 people ages 15-64
		Finance	Market capitalization of listed domestic companies, % of GDP
	Interaction (network)	Production	Share of firms exporting directly/indirectly (at least 10% of sales)
		Technology	Intellectual property payments per GDP (current US$ millions)
		Science	International co-authored scientific articles per 100,000 people
	Actors and capabilities	Production (capacity)	Gross fixed capital formation as % of GDP
		Production (quality)	ISO 9001 certificates per 10 million people
		Technology	Patents by residents, per million people
		Science	Scientific and technical articles, per million people
Demand articulation	Public sector		Public procurement as % of GDP
	Private (domestic) sector		ICT imports as a share of total imports
	Private (foreign) sector		Medium/high-tech exports as a share of total manufactured exports

Source: Authors' elaboration.

Reflexivity features a third level, which includes infrastructure that can be broken down into: 1) physical infrastructure, 2) information and communication technology (ICT) infrastructure, and 3) knowledge infrastructure. Physical infrastructure that is important for STI and industry development encompasses many things, such as transportation and logistics, residential and dwelling, city infrastructure, energy generation and distribution, and so on. Here we only focus on energy generation for two reasons: 1) it is essential for industrial development in the modern era, and 2) data availability. ICT infrastructure is another critical enabler for modern industries and STI capabilities. Knowledge infrastructure is important because innovative capabilities are cumulative and embedded with human capital (here, we use a generic level of human capital as a proxy for knowledge infrastructure[3-4]).

3 Measures of knowledge stock that calculate a cumulative number of patents or scientific articles are also used for this purpose. However, we believe human capital has more profound policy implications than knowledge stock, especially in the early stage of developing countries, because their knowledge stock has not yet accumulated and should be embedded with human capital.

4 "Gross graduation ratio" is a better indicator for our purpose. However, due to data limitation, we did not adopt it as an indicator. For the indicator, we have around 75 countries' data available, and only 34 possible for historical analysis (five of our 15 example countries) from the UNESCO database (http://data.uis.unesco.org/).

Institutions, which cover rules, regulations and laws that may affect innovation and industrial development processes and outcomes. They may guide resource allocation and actions of the participants while often affecting the level and distribution of outputs from innovation and industrial development. Despite their importance, it is hard to see institutions as indicators because they are not homogeneous across different countries nor readily quantifiable. A particular policy or law of a country is subject to the specific socioeconomic context of the country. Therefore, indicators for institutions are generally indirect and selective. Here, we focus on three areas of institutions: 1) gross R&D investment, 2) intellectual property protection, 3) entrepreneurial activities, and 4) financial investment.

R&D investment is one of the most critical measures indicating an innovation system's general strength and performance. Without a package of sound R&D-supporting institutions, a sizable investment in R&D from the public or private sector may not be possible. Hence, the size of R&D investment should collectively and indirectly indicate the effectiveness of R&D-supporting institutions (e.g. R&D tax credits, the conventions for government R&D appropriations, and policies for direct and indirect R&D performing institutes, among others). Hence, investment in R&D is proposed as the first category of institutions.

It is well known that intellectual property protection is crucial for innovators to be able to benefit from their own innovations (Cohen et al. 2000). Hence, this tool includes an indicator for measuring IP protection.[5] Similarly, the tool adopts a measure for the degree of entrepreneurial activities because a number of new businesses are crucial for turning innovations into industrial performances (Baumol 2002). Finally, we included an indicator to measure the overall strength of financing with the level of domestic financial investment.

The network component breaks down into international and domestic networks. While domestic networks such as public-private partnerships, industry-university collaboration, and innovation clusters are crucial in STI and industry capability development, their indicators are not readily available in developing countries. Imported technology and foreign direct investment play a crucial role in the early stage of industrial development (Rodrik 2018). We can measure international linkages of scientific collaboration and technology trades relatively directly and capital-embedded knowledge exchange indirectly through the degree of global value-chain participation. Hence, our network components deal with international networks in production, technology, and science, respectively.

Similarly, actors and capabilities focus on three sub-units: 1) production capability, 2) technological capability, and 3) scientific capability. These three units are roughly consistent with the main actors of innovation as discussed in the literature on triple helix (Etzkowitz and Leydesdorff 2000) or innovation systems (Lundvall 2007). We have not explicitly dealt with learning capability (such as the mode or speed of learning) or monitoring capability (as realized in the public or private think-tanks) because their indicator values are, unfortunately, not generally available.

5 We admit the limitations of patenting activities as measurements of innovation activities in that 1) not all innovations are patented, and 2) patenting becomes more pronounced from the upper-middle-income (UMI) stage, as shown in our analysis in Section 4. Still, level of patenting activities is generally believed to be a useful indicator for this purpose.

3 Methodology: Rationale, definition and calculation, and data sources and coverage

This section provides the rationale and definition of each indicator, and the formula of how we calculate the value from the data. Data sources and coverage are also included so that readers can apply other country's case to each indicator.

3.1 Reflexivity

Indicators under reflexivity depict, collectively, the overall status and performance of an innovation system. Hence, indicators in this category help policymakers better understand which components of their innovation systems perform well and which perform poorly, relative to other countries.

3.1.1 Infrastructure

We split the infrastructure component of innovation systems into physical, ICT and knowledge infrastructure. For physical infrastructure, we selected *electrical generation installed capacity* for its relevancy to industrial development and due to data availability. Transportation and logistics infrastructure, such as the length of road; volume; and frequencies of land, air, and sea traffic within and across countries are important but were not selected because they are less relevant to electricity when it comes to importance in industrial development. In addition, indicators for transportation are not as widely available nor as simple and representative as electricity generation. Similar logic was applied to the other sub-categories of physical infrastructure.

For ICT infrastructure, we selected *fixed broadband subscriptions*. A few alternatives were considered, such as the number of computers, wireline communication capacity and internet usage. However, this particular measure was determined to be the most appropriate way to assess the three principles: availability, relevancy and representativeness.

Similarly, *enrollment ratio in tertiary education* was chosen as a representative measure of knowledge stock. For knowledge stock, patent-based indicators also conform to our three principles and have been adopted in most indicator systems. However, we concluded that a human capital indicator (our indicator) is better suited to developing countries than patent-based indicators for two reasons. First, patentable inventions in developing countries are not as prominent and stable as in developed countries. Second, in the developing stages, fostering capable people precedes technology development including inventive activities. Therefore, human capital should be more relevant than inventive activities to building up innovative and industrial capability.

***Physical*:** Electric generation installed capacity (kW) per capita.

Rationale: Availability of electrical energy is an essential element for industrialization and innovation in a developing country. It is a proxy for measuring the quality of physical infrastructure (e.g. transport) required for innovation activities. The indicator measures a country's overall capacity to provide electricity.

Definition: Electricity generation capacity (kW) per capita in country *i*.

Data source and coverage: UN Energy Statistics Database,[6] available for 225 countries between 1990 and 2020. Population of country i is from World Bank data[7] and available for 214 countries between 1960 and 2020.

Calculation: Energy readiness (kW per capita) = total electricity generation installed capacity / total population.

***ICT*:** Fixed broadband subscriptions per 100 people.

Rationale: Access to fixed broadband is an essential element for industrialization and innovation activities in the current digital age. It is a proxy for measuring the quality of ICT infrastructure for innovation activities.

Definition and calculation: Number of fixed broadband subscriptions per 100 people in country *i*.

Data source and coverage: International Telecommunications Union (ITU), *World Telecommunication/ICT Indicators Database* via World Bank[8] and available for 206 countries between 1998 and 2020. Population of country *i* is from the World Bank data[9] and available for 214 countries between 1960 and 2020.

***Knowledge*:** Enrollment in tertiary education.

Rationale: Provision of sufficient human resources is an important necessary condition for industrialization of a developing country. Tertiary education is fundamental to learn, understand, absorb and adapt existing knowledge and, later, develop new knowledge. It is a proxy for measuring the quality of knowledge infrastructure for innovation activities.

Definition: Ratio of total enrollment numbers in tertiary education to the population in age for tertiary education.

Calculation: Enrollment ratio in tertiary education = number of people enrolled in tertiary education / population in the 5-year age group following secondary education.

Data source and coverage: UNESCO *UIS* database via World Bank[10] and available for 118 countries between 2010 and 2020.

6 See: http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC (accessed 13 Sep 2022).

7 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

8 See: https://data.worldbank.org/indicator/IT.NET.BBND.P2 (accessed 13 Sep 2022).

9 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

10 See: https://data.worldbank.org/indicator/SE.TER.ENRR?end=2020&start=2010 (accessed 13 Sep 2022).

3.1.2 Institution

For measuring the quality and robustness of institutions in a country, we find it relevant to include four important aspects: R&D investment, IPR protection, business friendliness and financial investment.

As a representative measure of R&D investment, we have selected *Gross expenditure on R&D as a share of GDP* (GERD as a share of GDP, or %GERD). GERD covers both public and private R&D to better encapsulate overall strength of the institutional mechanisms supporting R&D activities than either government expenditure on R&D or business expenditure on R&D.

For IPR protection, we have selected *patent application by non-residents per million people*. While domestic patents signify overall technological capability by domestic actors, the number of patents applied for by foreign applicants indicate not only the effectiveness of patent protection but also the market's attractiveness.

For institutional support to start-up formation, we have included *time (days) to start a business*, provided by the World Bank. Although there are several widely used indicators for start-up formation, including those offered by the Global Entrepreneurship Monitor, time (days) to start a business reflects institutional aspects more directly and the data is available for many more countries.

Lastly, for financial investment, we have included *market capitalization of listed domestic companies, % of GDP*, also from the World Bank. The stock exchange market is one of private firms' most important financing mechanisms. Market capitalization, in sum, indicates the overall strength of both financing mechanisms through the domestic stock market and the size of domestic firms.

R&D investment: Gross expenditure on R&D as a share of GDP.

Rationale: Gross expenditure on R&D illustrates a country's overall R&D efforts, indicating the quality of institutions and regulations on research and development in country *i*.

Definition and calculation: Gross expenditure on R&D over GDP, considering the size of a country.

Data source and coverage: Gross expenditure on R&D as a share of GDP and its composition between public and private sectors in country *i* is from the UNESCO *UIS* database via the World Bank[11] and available for 78 developing countries between 2010-2020.

IPR protection: Patent applications by non-residents, per million people.

Rationale: When a country's market size and absorptive capacity to utilize foreign technologies is weak, patent applications by non-residents will not occur. By contrast, if a country's market becomes meaningful and its absorptive capacity is sufficiently nurtured, non-residents begin to consider the market seriously and pursue technology transfer opportunities, putting pressure on a government to enforce strong IPR. This will enable an IPR regime to be properly established, which then will encourage non-residents to apply for patents. It is a proxy for a country's firmness of institutions and regulations in IPR.

Definition: Number of patents applied for by foreign nationals over million people in a country.

Calculation: IPR protection level = number of patents applied for by non-residents / total population * 1,000,000.

11 See: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS (accessed 13 Sep 2022).

Data source and coverage: World Intellectual Property Organization (WIPO) via the World Bank[12] and available for 123 countries between 1980 and 2020. Population of country *i* is from World Bank data[13] and available for 214 countries between 1960 and 2020.

Business: New business density as new business registrations per 1,000 people ages 15-64.

Rationale: Entrepreneurship and creation of new firms is very important in the dynamism of a country's economy. It is assumed that entrepreneurial activities will increase if institutions of business are well established and friendly and the level of bureaucracy is low.

Definition and calculation: Number of newly registered firms over the past seven years per 1,000 people ages 15-64.

Data source and coverage: New business density in country *i* is from World Bank's Entrepreneurship Database[14] and available for 170 countries between 2006 and 2020.

Finance: Market capitalization of listed domestic companies, % of GDP.

Rationale: New business is actively launched if institutions and regulations are friendly and entrepreneurship is strong in a country. Market capitalization of listed domestic companies in a country will be high compared to its GDP if institutions and regulations for business are properly established and start-up activity is strong in country *i*.

Definition and calculation: Total market capitalization of listed domestic companies over GDP in a country.

Data source and coverage: World Federation of Exchanges via the World Bank[15] and available for 102 countries between 1975 and 2020.

3.1.3 Interaction (network)

For measuring the level of international relationships in production, technology and science, we selected indicators related to exports, intellectual property payments and scientific journal co-authorship, respectively.

Production: Share of firms exporting directly/indirectly (at least 10% of sales).

Rationale: Firms participating in exporting goods (directly/indirectly) can be exposed more frequently to new knowledge from advanced foreign countries in their activities of production, marketing and sales. Through their exporting network, interactions between domestic firms and their foreign counterparts can occur in the form of importing capital goods or components, and informal knowledge transfer through original equipment manufacturer (OEM)/original design manufacturer (ODM) contracts. This indicator is a proxy for measuring the level of interaction between domestic and foreign companies at the production level.

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12 See: https://data.worldbank.org/indicator/IP.PAT.NRES (accessed 13 Sep 2022).

13 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

14 See: https://data.worldbank.org/indicator/IC.BUS.NDNS.ZS (accessed 13 Sep 2022).

15 See: https://tcdata360.worldbank.org/indicators/CM.MKT.LCAP.GD.ZS?country=BRA&indicator=1550&viz=line_chart&years=1975,2020 (accessed 29 Nov 2022).

Definition and calculation: Measured by a firm-level survey of the share of firms exporting their products directly/indirectly, at least 10% of their sales, in a country.

Data source and coverage: World Bank Enterprise Survey[16] and available for 231 countries between 2003 and 2019.

Technology: Intellectual property payments per GDP (current US$ millions).

Rationale: Intellectual property payments are a country's cost for utilizing advanced foreign technologies. Through the purchase of foreign intellectual properties, developing countries have more opportunities to learn new knowledge from abroad. It is a proxy for measuring the level of interaction at technology level with foreign countries for new knowledge.

Definition: Intellectual property payments over GDP (US$ millions) in a country, considering the size of each country's economy.

Calculation: Interaction in technology = intellectual property payments / total GDP (US$ 1,000,000).

Data source and coverage: International Monetary Fund, *Balance of Payments Statistics Yearbook* and data from the World Bank,[17] and available for 196 countries between 1960 and 2020.

Science: International co-authored scientific articles per 100,000 people.

Rationale: Access to the international scientific research community is very important to stay at the frontier of science. It is a proxy for measuring the level of interaction with the international scientific research community.

Definition: Number of international co-authored scientific articles in a country that includes at least one author from the country, per 100,000 people, considering the size of a country's population.

Calculation: Interaction in science = number of international co-authored scientific articles / total population * 100,000.

Data source and coverage: International co-authored scientific articles per 100,000 people in country *i* is from Scival, Scopus[18] and available for 207 countries between 2011 and 2021. Population of country *i* is from the World Bank [19] and available for 214 countries between 1960 and 2020.

3.1.4 Actors and capabilities

For indicators measuring productive, technological and scientific capability, we included ISO 9001 certificates, the number of patents, and the number of scientific and technical journal articles. Patents and scientific articles are already widely used as indicators for technological and scientific capabilities at the country level. ISO 9001 certificates have the advantage of indicating not just productivity or the amount of production but also the quality of production processes, which should be one of the policy goals for industrial development in developing countries.

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16 See: https://www.enterprisesurveys.org/en/data/exploretopics/trade (accessed 13 Sep 2022).

17 See: https://data.worldbank.org/indicator/BM.GSR.ROYL.CD (accessed 13 Sep 2022).

18 See: https://www.scival.com/, (accessed 13 Sep 2022). The data retrieved is presented in Appendix II.

19 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

Production (quality): ISO 9001 certificates per 10 million people

Rationale: ISO 9001 is an international standard accredited by the ISO (the International Organization for Standardization) that indicates whether a firm is qualified for an international standard in terms of quality management systems. Number of ISO 9001 certificates is a proxy for the operational efficiency, production capabilities of companies in a country.

Definition: Number of ISO 9001 certificates obtained by a country, over 10 million people, considering the size of a country's population.

Calculation: Operational efficiency = ISO 9001 certificates / total population * 10,000,000.

Data source and coverage: Number of valid ISO 9001 certificates acquired by country *i* is from The ISO Survey of Management System Standard Certifications 2020[20] and available for 195 countries between 2018 and 2020[21]. Population of country i is from the World Bank Data[22] and available for 214 countries between 1960 and 2020.

Production (capacity): Gross fixed capital formation as % of GDP.

Rationale: Gross fixed capital formation is used for measuring the addition of investment in the production activities of a country and, therefore, a proxy for the increase of the production capacity of a country.

Definition and calculation: This indicator is in addition to the fixed assets that include land improvements; plant, machinery, and equipment purchases; and the construction (World Bank 2022) and net changes in inventories by firms in a country, considering the size of a country's economy size with GDP.

Data source and coverage: World Bank national accounts data and OECD national accounts data via the World Bank[23] and available for 159 countries between 1960 and 2020. Population of country *i* is from the World Bank[24] and available for 214 countries between 1960 and 2020.

Technology: Patent applications per million residents.

Rationale: The number of patents filed by residents in country *i* shows the country's capability to innovate and create new knowledge and technology. It is a proxy for measuring the technological capability of a country.

Definition: Number of patents filed by resident through the Patent Cooperation Treaty or a national patent office, per million people in a country.

Calculation: Capabilities in technology = number of patent filed by residents / total population * 1,000,000.

20 https://www.iso.org/the-iso-survey.html (accessed 13 Sep 2022).

21 ISO 9001 had been updated in 2015 and as the certificate is reissued every three years, only the data from 2018 is consistent for analysis.

22 https://data.worldbank.org/indicator/SP.POP.TOTL

23 See: https://data.worldbank.org/indicator/NE.GDI.FTOT.ZS (accessed 29 Nov 2022).

24 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

Data source and coverage: The number of patent applications filed by residents in country *i* is from the WIPO via World Bank[25] and available for 234 countries between 1980 and 2020. Population of country *i* is from the World Bank Data[26] and available for 214 countries between 1960 and 2020.

Science: Scientific and technical articles, per million people.

Rationale: The number of scientific and technical articles published by country *i* demonstrates a country's capability in science. It is a proxy for measuring the capability of a country's basic science.

Definition: Number of scientific and technical journal articles published per 1,000,000 people in a country.

Calculation: Capability in Science = number of scientific and technical articles / total population * 1,000,000.

Data source and coverage: National Science Foundation, Science and Engineering Indicators via the World Bank[27] and available for 133 countries between 2000 and 2018.

3.2 Demand articulation

Demand articulation must follow the individual context, structure and capabilities that each country possesses. Reflecting various external and internal factors discussed in the previous sections, policy analysts and policymakers need to identify and articulate demands for specific industries or products and the need for import substitution of specific products or technologies before they set specific policy goals and programmes. Because of the contextual nature of demands and needs, identifying appropriate indicators for demand articulation that can be generally useful across different countries is problematic. The best available indicators for demand articulation are somewhat broad (such as the overall role of the public sector in market formation) or highly selective (for example, the role of the ICT sector in the domestic market or high-tech manufacturing in the international production network).

3.2.1 Public sector

Public sector: Public procurement as % of GDP.

Rationale: Public procurement is an important tool for a government to direct and create markets for new technologies. Ideally, the share of strategic public procurement is available, which in many countries includes a high component of innovation. In the absence of this level of granularity, general public procurement is a proxy for measuring a government's capacity or willingness to articulate demand in the public sector. The role of public procurement as an important industrial policy tool becomes more prominent with the rising importance of sustainable development.

Definition and calculation: Size of public procurement as a share of GDP in country *i*.

25 See: https://data.worldbank.org/indicator/IP.PAT.RESD (accessed 13 Sep 2022).

26 See: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed 13 Sep 2022).

27 See: https://data.worldbank.org/indicator/IP.JRN.ARTC.SC (accessed 13 Sep 2022).

Data source and coverage: Government at a Glance, OECD,[28] available for 37 OECD countries and five non-OECD countries, and the Global Public Procurement Database[29] between 2007 and 2019 and 54 non-OECD countries between 2018 and 2019.

3.2.2 Private sector

***Private (domestic)*:** ICT imports as a share of total imports.

Rationale: The ratio of ICT imports to total imports indicates the importance of ICT content to a country's overall imports. It may significantly increase if a country participates in the global value chain of the ICT sector by attracting foreign direct investments (FDI) or by directing domestic companies to the ICT sector. An increase in the ratio can be interpreted as a country's industrial upgrading to digitalization. This indicator is a proxy for measuring a country's capacity to articulate demand in the domestic ICT sector.

Definition and calculation: Share of ICT imports to total imports in country *i*.

Data source and coverage: UNCTAD's *UNCTADstat* database via the World Bank[30] and available for 170 countries between 2000 and 2020.

***Private (foreign)*:** Medium- and high-tech exports as a share of total manufactured exports.

Rationale: Share of medium- and high-tech exports in total manufactured exports indicates the quality of a country's export products. The share will increase over a certain period in the course of a country's successful industrial upgrading, which demonstrates a country's successful direction of their resources to more lucrative market.

Definition and calculation: Share of medium- and high-tech exports in total manufactured exports in country *i*.

Data source and coverage: UNIDO's *Competitive Industrial Performance (CIP)* database via the World Bank[31] and available for 151 countries between 1990 and 2019.[32]

28 See: https://stats.oecd.org/Index.aspx?QueryId=107598 (accessed 13 Sep 2022).

29 See: https://www.globalpublicprocurementdata.org/gppd/ (accessed 13 Sep 2022).

30 See: https://data.worldbank.org/indicator/NV.MNF.TECH.ZS.UN (accessed 13 Sep 2022).

31 See: https://data.worldbank.org/indicator/TX.MNF.TECH.ZS.UN (accessed 13 Sep 2022).

32 Alternative data is OECD - Trade in Value Added via World Bank (https://tcdata360.worldbank.org/indicators/dom.val.ex.all) and available for 62 countries between 1995-2014.

4 Examples using quantitative and qualitative policy data

In this section, we provide examples of country diagnosis using the tool proposed in this report. To test applicability of the tool, 15 countries from a developing country group and five from a developed country group are diagnosed across eight indicators. First, we briefly explain the selection process, then present the results of the diagnosis.

4.1 Selection of countries for diagnosis

In order to select representative developing countries, we find it relevant to employ categories of geographical region, income group and industry structure. For geographical regions and income group, we use World Bank classifications.[33] Our geographical regions include East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, South Asia, and Sub-Saharan Africa. There are four income group categories: low-income (LI) economies ($1,045 or less), lower-middle-income (LMI) economies ($1,046 to $4,095), upper-middle-income (UMI) economies ($4,096 to $12,695), and high-income (HI) economies ($12,695 or more).

For industry structure of the developing country group (all countries except high-income group), we looked at the compositions of the value added by the manufacturing sector as well as the agriculture, forestry, and fishing sector as % of GDP, and carried out a cluster analysis for 116 developing countries that have data. The results of the cluster analysis are as follows. Three cluster groups, or Categories[34] are identified, which suggest a progressive trajectory of structural change from agriculture to manufacturing activities. These categories can be presented by looking at two relative extreme cases, Category 1 and Category 3, respectively. Category (1) includes five countries with the highest value-added portion of the agriculture/forestry/fishing sector and the lowest value-added portion of the manufacturing sector, relative to other countries in the sample. At the opposite end, Category (3) includes 71 developing countries with the lowest value-added portion of the agriculture/forestry/fishing sector and the highest value-added portion of the manufacturing sector. Finally, Category (2) includes 40 countries with a share of value-added from agriculture/forestry/fishing sector higher than the observed in countries in Category 1, but lower than that observed in countries in Category (3). Similarly, while the value-added portion of the manufacturing sector is higher than that of countries in Category (1), it is below the share of countries in Category (3). In case of Category 1, all five countries belong to the low income group from Sub-Saharan Africa. Compositions of Category 2 and Category 3 countries are illustrated in Tables 4 and 5, respectively.

We then selected 20 countries—five HI economies and 15 developing countries—to represent the geographical, income and industrial structure diversity of the analysis (Table 6).

For benchmarking high-income countries, we have selected five countries that represent each region: the Republic of Korea (RoK), East Asia and Pacific; Germany, Europe & Central Asia; Canada, the Americas; Israel, from Middle East & North Africa; and Australia, East Asia & Pacific. In particular, the RoK was selected as a successfully industrialized country that emphasizes heavy investment in an STI system led by the central government. It has transformed from an agriculture-based LI economy to a high-tech based HI economy within a half century, during the second half of the twentieth century. Both Germany and Canada are HI countries from Europe and North America, respectively. Israel is also well known for its strong commitments to STI and entrepreneurship.

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33 See: https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries (accessed 19 May 2022).

34 See Annex 1 for the list of countries in each category.

Table 4. Category 2 countries

REGION	LI COUNTRY	LMI COUNTRY	UMI COUNTRY	TOTAL
East Asia & Pacific		7	2	9
Europe & Central Asia		2	1	3
Latin America & Caribbean		2	1	3
Middle East & North Africa				
South Asia		4		4
Sub-Saharan Africa	12	9		21
Total	**12**	**24**	**4**	**40**

Source: Authors' elaboration.

Table 5. Category 3 countries

REGION	LI COUNTRY	LMI COUNTRY	UMI COUNTRY	TOTAL
East Asia & Pacific		5	4	9
Europe & Central Asia		2	14	16
Latin America & Caribbean		4	14	18
Middle East & North Africa	1	7	3	11
South Asia		2	1	3
Sub-Saharan Africa	1	7	6	14
Total	**2**	**27**	**42**	**71**

Source: Authors' elaboration.

Table 6. Selected countries for exemplary diagnosis

REGION	LI COUNTRY	LMI COUNTRY	UMI COUNTRY	HI COUNTRY
East Asia & Pacific (6)		Cambodia (C2) Indonesia (C3)	China (C3) Thailand (C3)	RoK Australia
The Americas (4)		Honduras (C3)	Peru (C3) Costa Rica (C3)	Canada
Middle East & North Africa (3)		Morocco (C3)	Jordan (C3)	Israel
Europe & Central Asia (3)		Uzbekistan (C2)	Romania (C3)	Germany
Sub-Saharan Africa (4)	Ethiopia (C1) Uganda (C2)	Kenya (C2)	South Africa (C3)	
Total: 20	**2**	**6**	**7**	**5**

Note: C1 = Category 1, C2 = Category 2, C3 = Category 3. *Source:* Authors' elaboration.

4.2 Exemplary diagnosis of the indicator system

This section presents the results of the exemplary diagnosis for all 20 countries across all indicators. In general, there are two types of presentation. First, when data is sufficiently available,[35] four types of analysis are shown: 1) a column chart showing each country's performance compared to the average within its income group, 2) a scatter-plot chart with horizontal axis of growth (improvement rate), 3) then a transition path[36] from LI, LMI or UMI to HI status, based on average values of each income group, and 4) the historical path of recently industrialized countries RoK and China, validating the transition path drawn from the diagnosis. Second, when data is not sufficient for the aforementioned analyses,[37] two types of analysis are presented: 1) results from a column chart showing each country's performance compared to the average within its income group and a scatter-plot chart with a horizontal axis of GDP per capita with an extrapolation equation; 2) results from a column chart showing each country's performance compared to the average within its income group and the transition path of RoK and China.

4.2.1 Reflexivity: Infrastructure

Energy readiness: Electric power generation installed capacity (kW) per capita.

1) *Electric power generation installed capacity per capita of selected countries in each income group:*

Higher-income countries tend to have more electric power generation capacity than lower-income countries, as shown in Figure 2. This confirms the assumption and validity of this indicator.

- Average electric power generation capacity per capita in LI, LMI, UMI and HI countries is 47kW, 248kW, 1,187kW and 2,480kW, respectively.
- The higher the income of a country, the larger the electric power generation capacity. From LI to LMI countries the value of the indicator expands by 547%, from LMI to UMI by 479%, and from UMI to HI by 209%.

2) Electric power generation installed capacity per capita and its relative change over the last 10 years:[38]

- Figure 3 shows the electric power generation capacity per capita and its relative changes over the last 10 years for the four income groups and 20 selected countries.
- Global average electric power generation capacity per capita and the relative change over the ten-year period are 953kW and 32%, respectively.
- While the value of electric power generation capacity per capita in Cambodia is still lower than the average value of the LMI group, the improvement rate over the last 10 years is higher than the group average.
- Thailand is the only country that decreased over the last 10 years among the selected countries in terms of the indicator.

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35 Here, "sufficiently available" means that data is not only available for many countries in recent years but also historically sufficient over a certain period.

36 We do not intend to argue that all and current developing countries should follow the transition path presented in our analysis. See section 7 for detailed discussions.

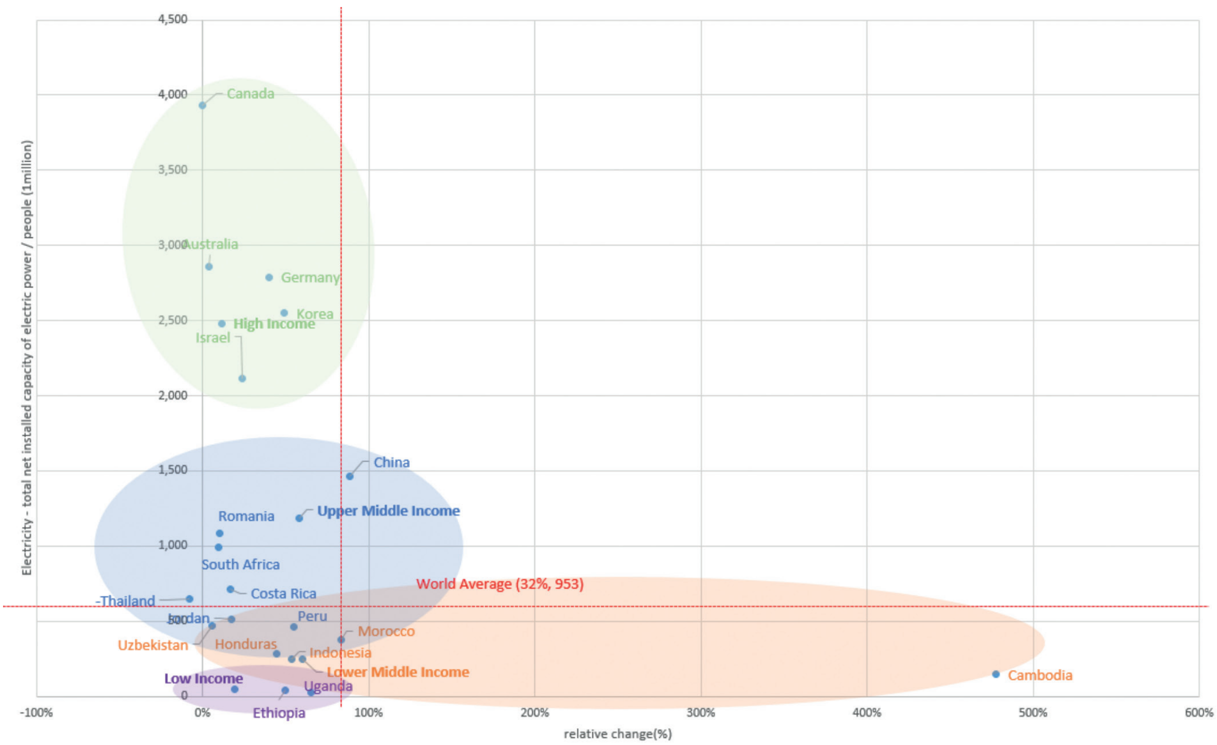
37 They include indicators for the share of firms exporting directly/indirectly (at least 10% of sales), number of ISO certificates per 10 million people, and public procurement as % of GDP.

38 With data limitations, recent and reference years vary across countries in this analysis throughout the document.

Figure 2. **Electric power generation installed capacity (kW) per capita in 2019[39], selected countries**

Source: Authors' elaboration.

Figure 3. **Energy readiness and its relative change, 2010-2019[40], selected countries**



Source: Authors' elaboration.

39 The recent year that the majority of analysed countries have data is presented.

40 The recent year that the majority of analysed countries have data is presented.

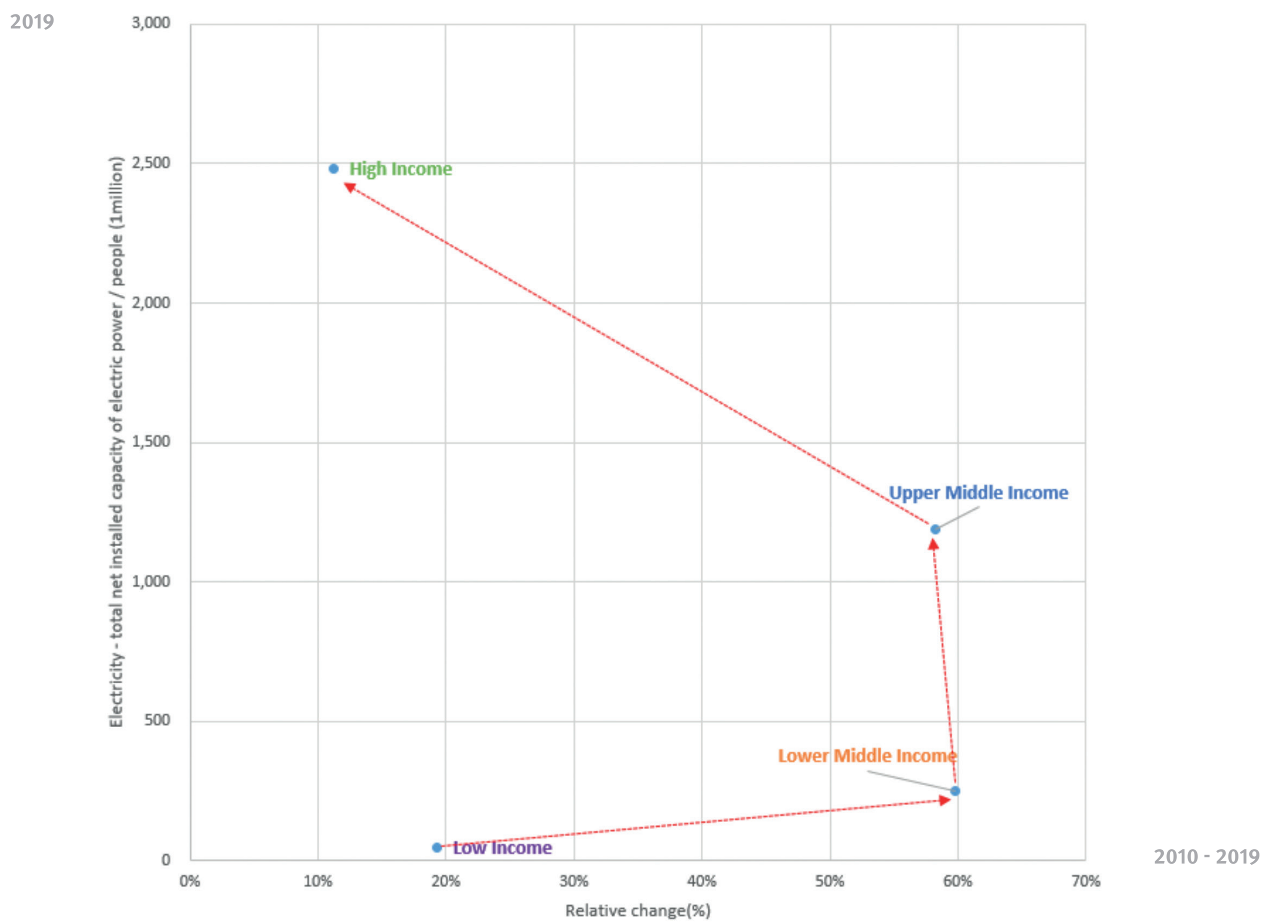
3) Transition path from LI to HI countries:

- From LI, LMI, UMI to HI countries, the transition path follows a counter-clockwise direction as shown in Figure 4.
- While the average LMI growth rate is higher than the LI rate, capacity growth is significantly higher between the HI group and both the UMI and LMI groups.
- Although HI electric capacity is higher, the growth rate is lower than for other income groups, suggesting that HI countries have reached the peak of power generation.
- This pattern suggests a transition path for a country undergoing successful industrial development.

4) Time series of energy readiness in RoK and China:

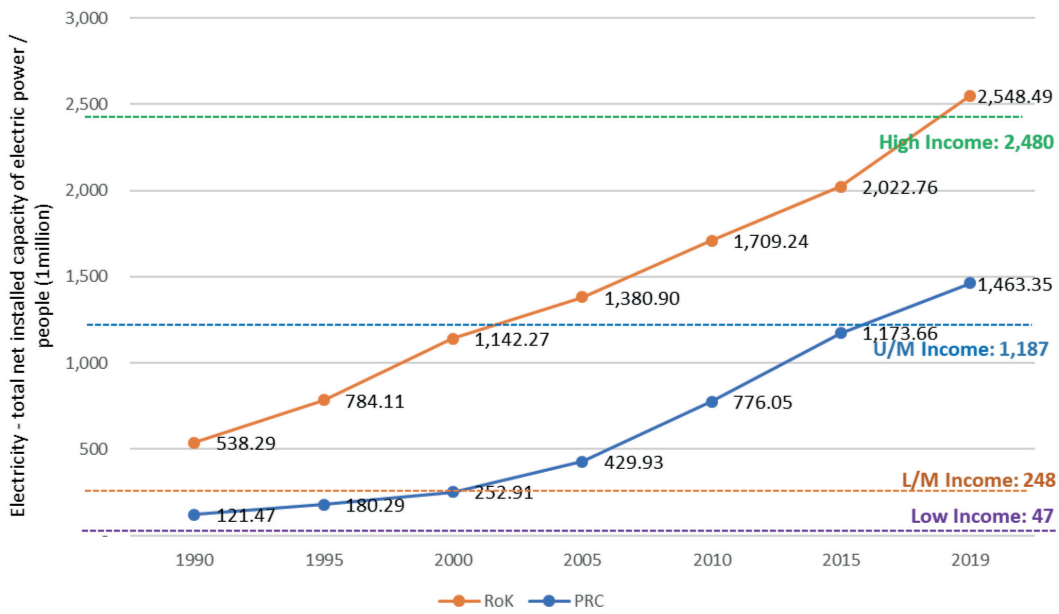
- Figure 5 shows the change in energy readiness in RoK and China between 1990 and 2020. Both countries have succeeded in industrialization since the late 20th century.
- RoK steadily increased its electric power generation capacity throughout the period, yet growth has slowed since the 2010s.
- China's growth rate began to take-off from early the 2000s and recently surpassed the UMI group average.

Figure 4. LI to HI transition path of energy readiness, selected countries



Source: Authors' elaboration.

Figure 5. **Change in energy readiness, RoK and China, 1990-2019**



Source: Authors' elaboration.

Digital connectivity: Fixed broadband subscriptions per 100 people.

1) *Fixed broadband subscriptions per 100 people of selected countries in each income group:*

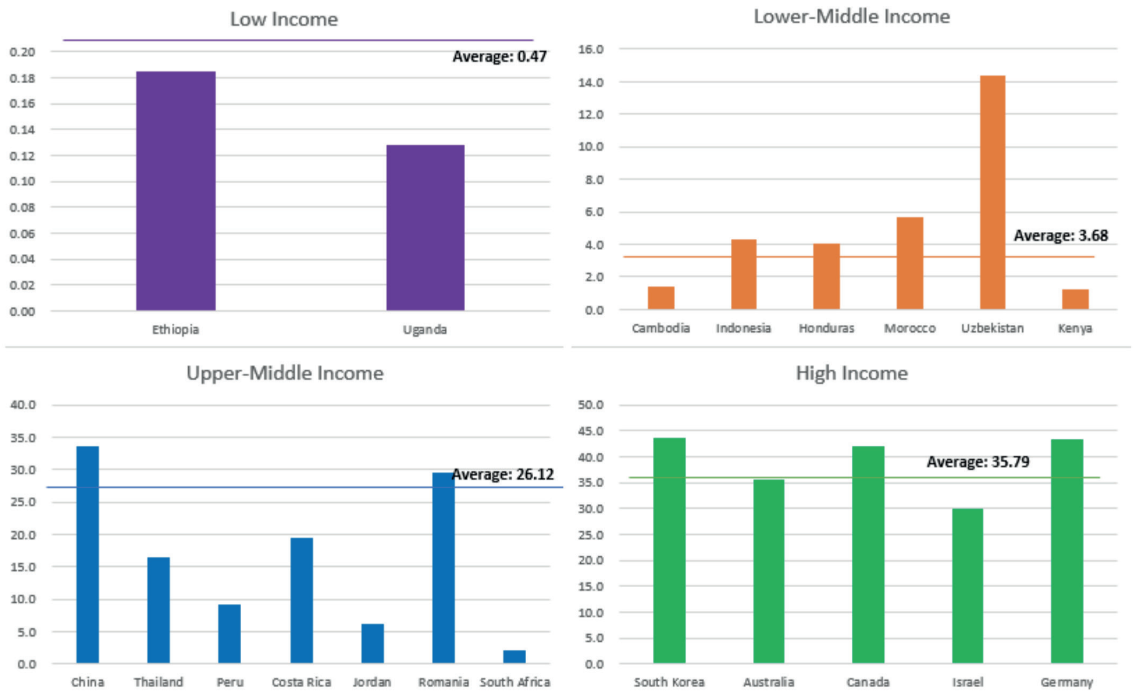
Higher-income countries tend to have more fixed broadband subscriptions than lower-income countries.

- As shown in Figure 6, average fixed broadband subscriptions per 100 people in LI, LMI, UMI and HI countries is 0.47, 3.68, 26.12 and 35.79, respectively.
- Average value of the indicator increases by 682% from LI to LMI countries; 609%, from LMI to UMI; and 37% from UMI to HI countries.
- Uzbekistan is far beyond the LMI average, while Cambodia and Kenya place far below the LMI average. In the UMI group, Peru, Jordan and South Africa are all below the group's average.

2) Fixed broadband subscriptions per 100 people and its relative change over the last 10 years:

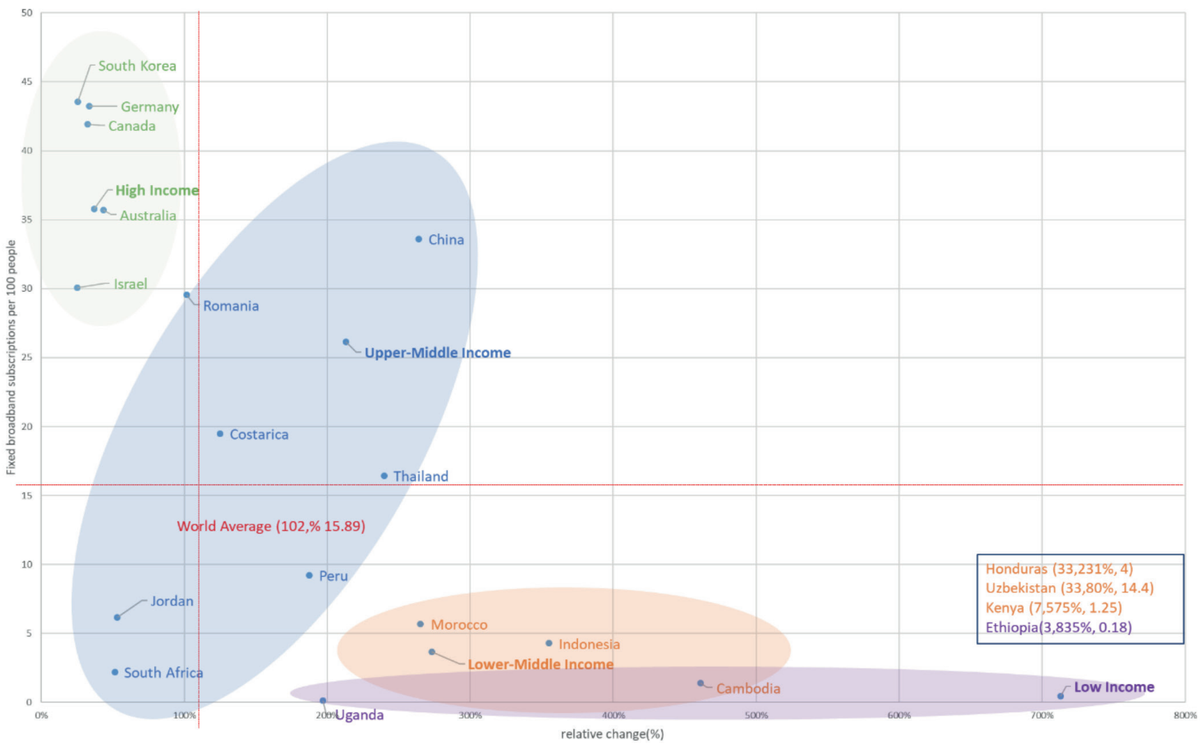
- Figure 7 shows fixed broadband subscriptions per 100 people and its relative changes over the last 10 years for the four income groups and 20 selected countries.
- Global average fixed broadband subscriptions per 100 people and the relative change for the ten-year period are 15.89 and 102%, respectively.
- Values for LI and LMI countries are horizontally dispersed from their group's average value while there is a vertical dispersion in UMI and HI countries.
- Within the LI group, the value for Ethiopia appears much further to the right of the chart than the value for the group average, while that of Uganda is further to the left. For LMI countries, Honduras, Uzbekistan and Kenya deviate further right from the group's average value. This indicates that digital connectivity in these countries has significantly increased compared to the groups' average over the last 10 years.
- Values for UMI and HI countries are more densely dispersed than LI and LMI countries.

Figure 6. Fixed broadband subscriptions per 100 people in 2020, selected countries



Source: Authors' elaboration.

Figure 7. Digital connectivity and its relative change, 2010-2020, selected countries



Source: Authors' elaboration.

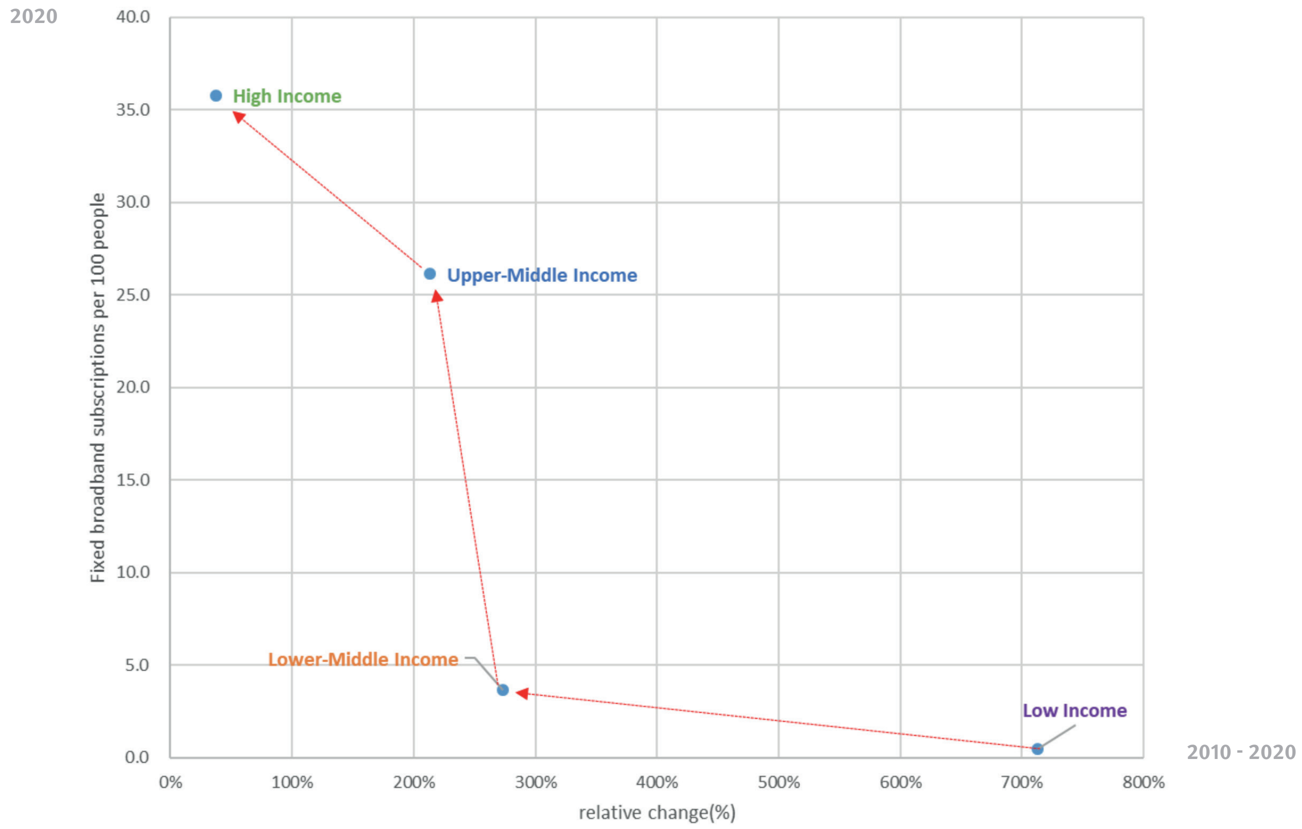
3) Transition path from LI to HI countries:

- From LI to HI countries, the transition path proceeds on a left, upward direction, similar to a reverse exponential curve, as shown in Figure 8.
- While the value of the LI group average is low, the growth rate is significantly higher than those of other income groups.
- The growth rate decreases along the income level, and the gap is largest between the LI and LMI groups. Fixed broadband subscriptions increase along the income level, and the gap is largest between the LMI and UMI groups.
- Growth rate for HI countries is lower than for other groups.

4) Time series of digital connectivity in RoK and China:

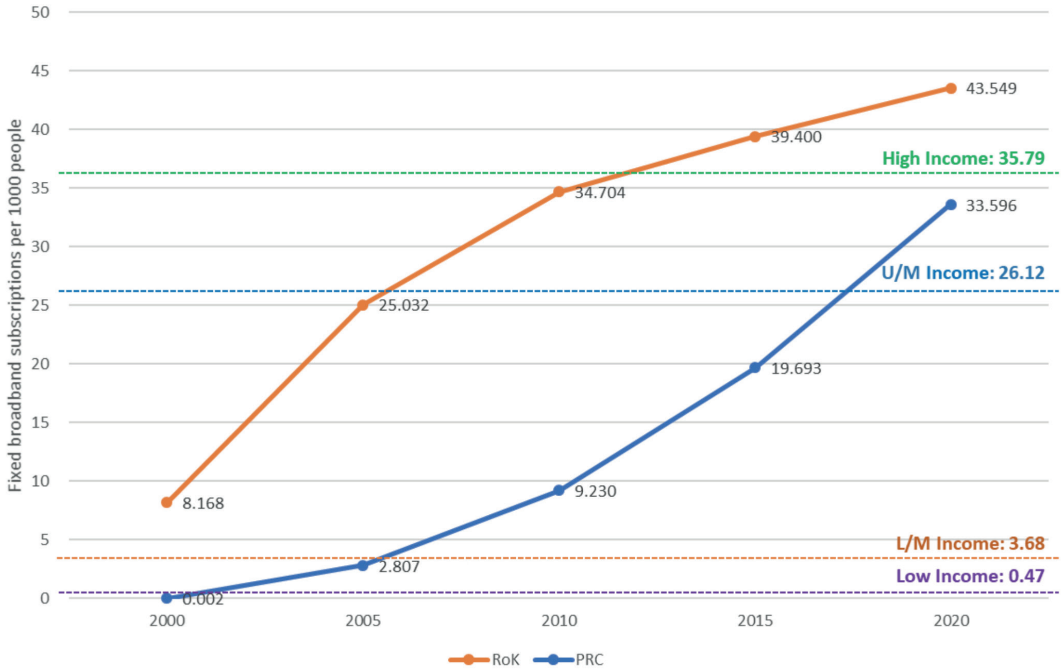
- Figure 9 shows change in fixed broadband subscriptions in RoK and China between 2000 and 2020.
- While subscriptions in RoK significantly increased during the early 2000s, the growth rate slowed after surpassing the level of HI group.
- Subscriptions in China increased from the late 2000s and still exhibit a strong growth rate.

Figure 8. LI to HI transition path of digital connectivity, selected countries



Source: Authors' elaboration.

Figure 9. Change in digital connectivity, RoK and China, 2000-2020



Source: Authors' elaboration.

Knowledge: Enrollment in tertiary education, % of gross enrollment.

1) Enrollment ratio in tertiary education of selected countries in each income group:

Higher-income countries have a higher tendency to enroll for tertiary education than lower-income countries.

- Average enrollment ratios in LI, LMI, UMI and HI countries are 9%, 27%, 58% and 79%, respectively, as shown in Figure 10.
- As income increases, the enrollment ratio from LI to LMI countries increases by 18%; from LMI to UMI, by 31%; and from UMI to HI, by 21%.

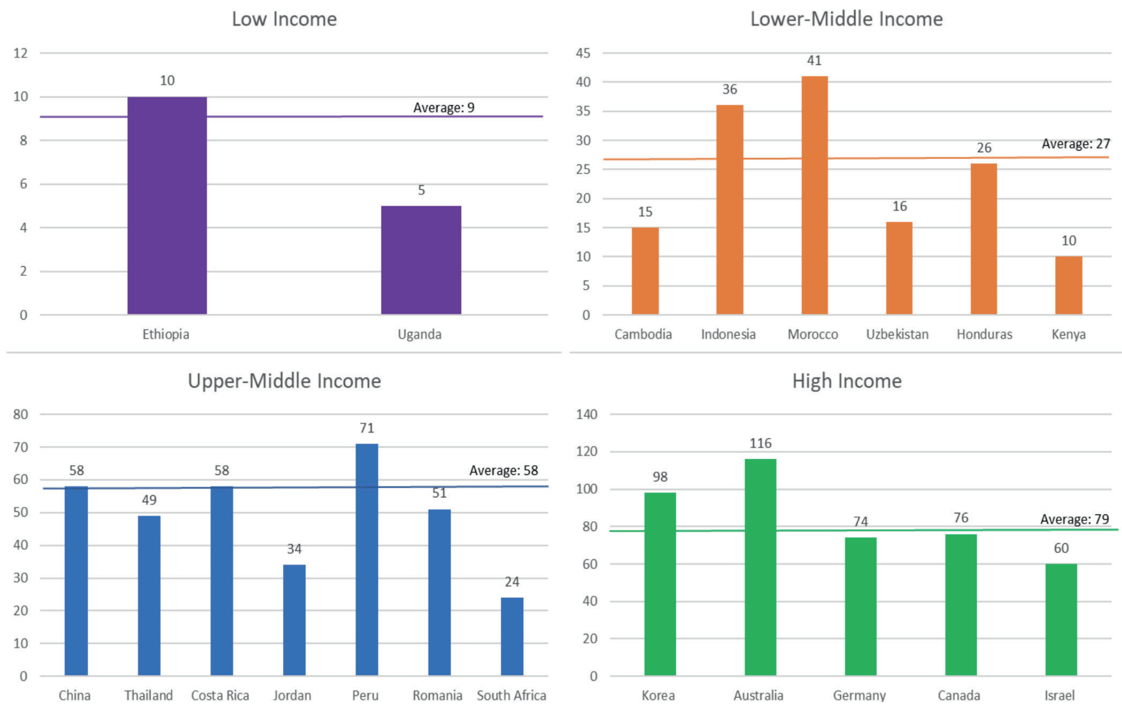
2) Enrollment ratio in tertiary education and its relative change over the last 10 years:[41]

Figure 11 shows the enrollment ratio in tertiary education and its relative change over the last 10 years for the four income groups and 20 selected countries.

- Global enrollment ratio and its relative change for the world are 40% and 30%, respectively.
- LI and HI countries generally do not deviate from their average values, while there is large variation among LMI and UMI countries.
- Ethiopia deviates further right from the average value of LI countries according to the data displayed on the figure, indicating that its relative change has significantly increased over the last 10 years (2008-2018).
- Over the last 10 years, relative change in LI is 15%, while relative changes in LMI and UMI are 45% and 78%, respectively. However, HI countries with high ratios demonstrate very low growth rates.

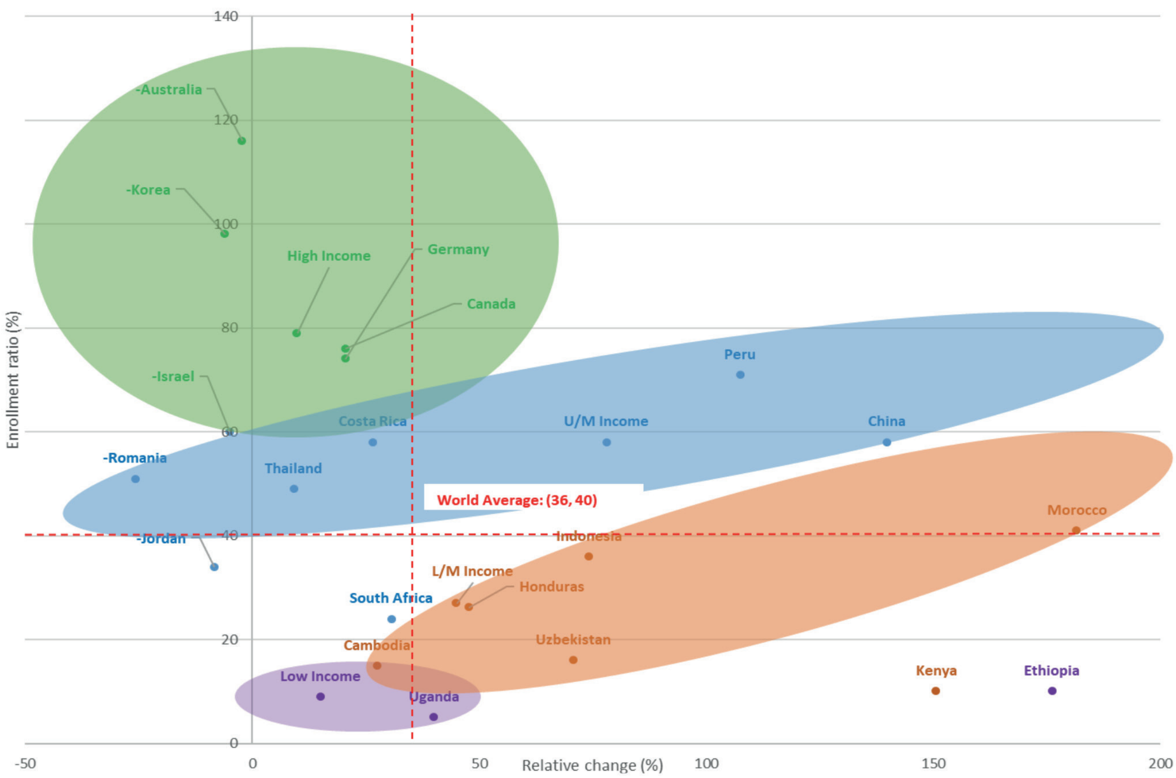
41 Due to data limitations, recent and reference years vary across countries in this analysis.

Figure 10. Enrollment ratio in tertiary education in 2020, selected countries



Source: Authors' elaboration.

Figure 11. Enrollment ratio in tertiary education and its relative change, 2010-2020, selected countries



Source: Authors' elaboration.

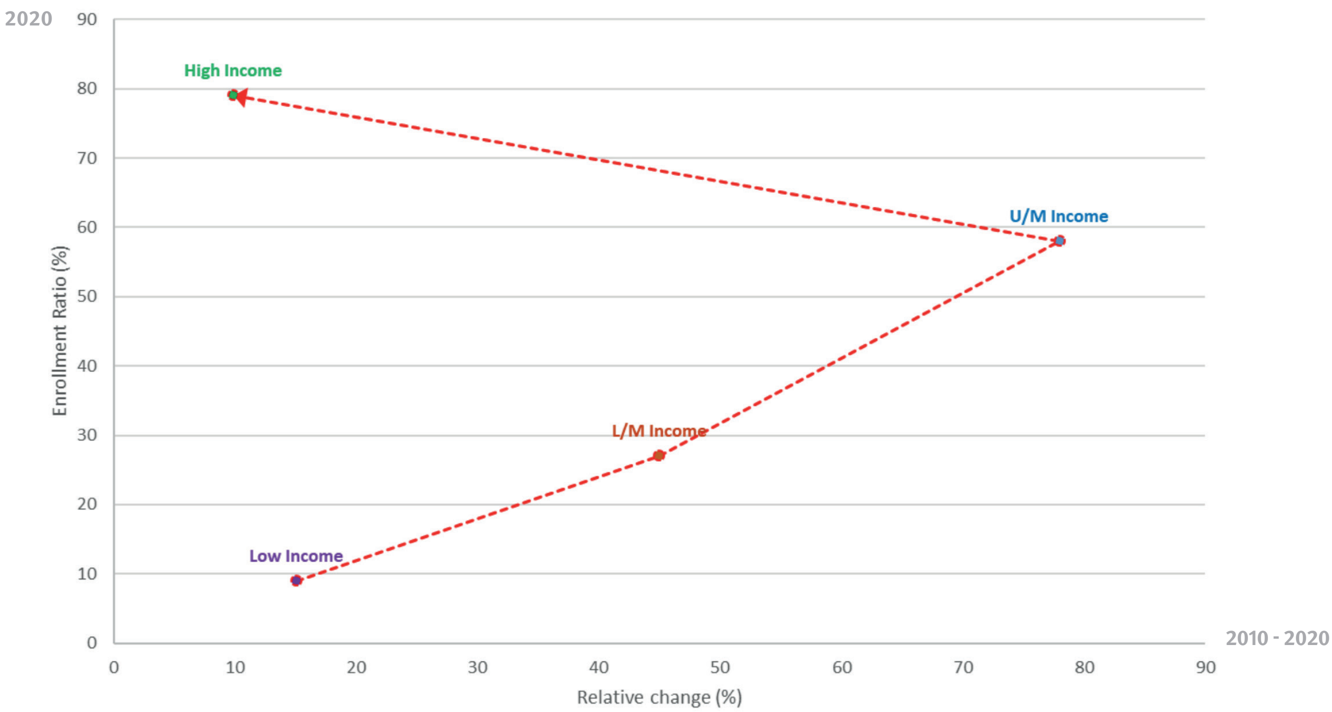
3) Transition path from LI to HI countries:

- The transition path follows the counterclockwise direction when plotting the indicator vs relative change, as shown in Figure 12.
- If a specific country undergoes successful industrial upgrading, it is expected to show a similar pattern.

4) Time series of enrollment ratio in tertiary education in RoK and China:

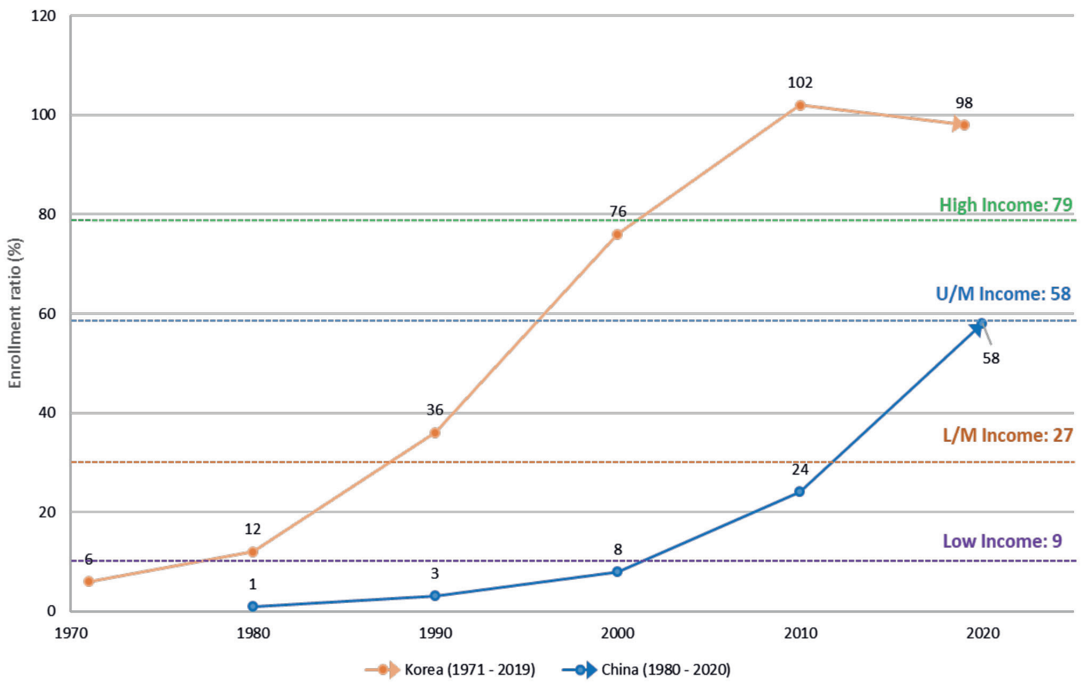
- Plotting in Figure 13 using data from RoK (1971-2019) and China (1980-2020) follows a typical S-curve.
- In RoK, an HI country, the sudden increase in enrollment ratio began in the early 1980s and stagnated around 2010, while in China, which belongs to the UMI group, the increase occurred around 2000 and the enrollment ratio has continued to grow since then.

Figure 12. LI to HI transition path of enrollment ratio in tertiary education, selected countries



Source: Authors' elaboration.

Figure 13. Change over time in enrollment ratio in tertiary education, RoK and China



Source: Authors' elaboration.

4.2.2 Reflexivity: Institution

R&D investment: Gross expenditure on R&D (GERD) as a share of GDP.

1) Gross expenditure on R&D as a share of GDP of selected countries in each income group:

Higher-income countries tend to have higher R&D expenditure per GDP than lower-income countries, as shown in Figure 14.

- Average R&D expenditure per GDP in LMI, UMI and HI countries is 0.53, 2.00 and 2.97, respectively.
- As income increases, the average value of R&D expenditure per GDP from LMI to UMI increases by 277%, and from UMI to HI by 48%.
- Within the LMI group, values for Morocco and Kenya are located above the average on the figure, while others are placed far below the average. Within the UMI group, China records higher than the average expenditure while other countries are below the average. Within the HI group, expenditures for RoK and Israel are far above the average.

2) Gross expenditure on R&D as a share of GDP and its relative change over the last 10 years:[42]

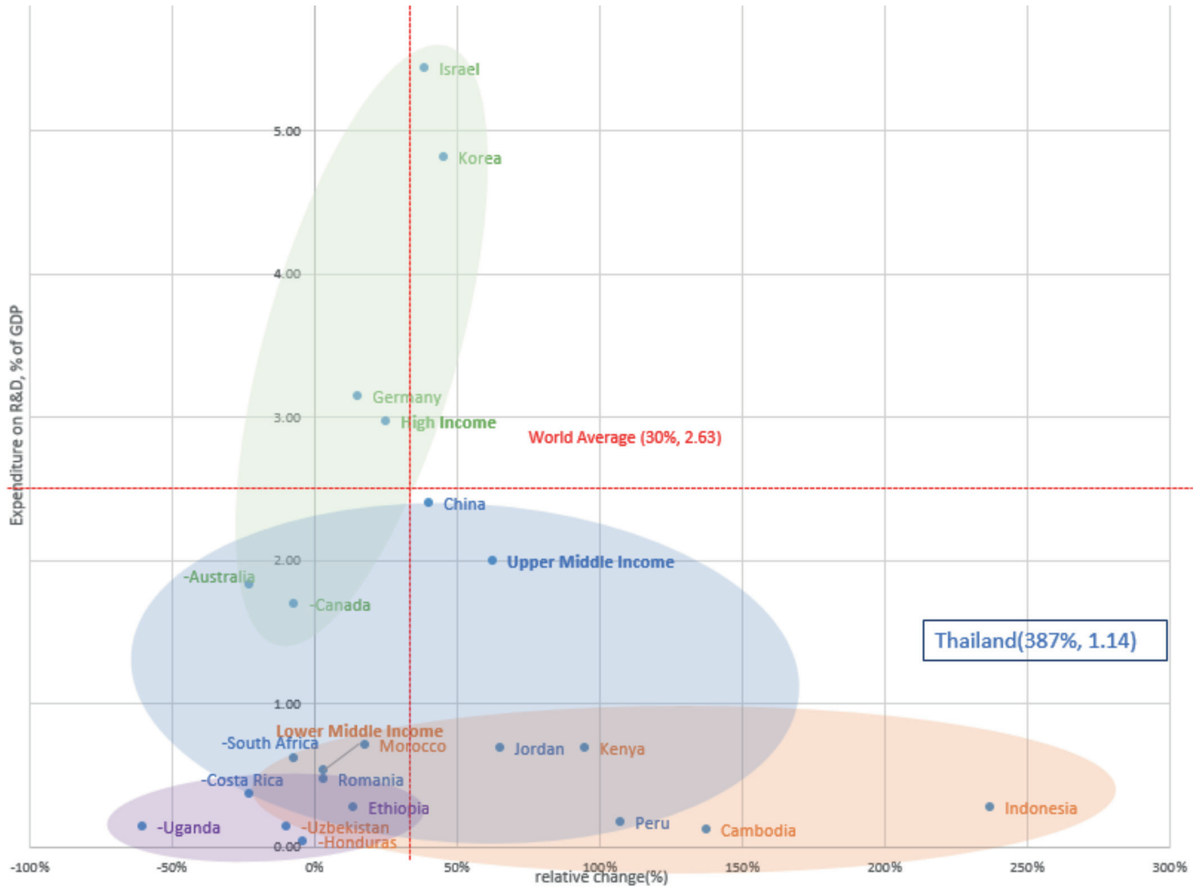
- Figure 15 shows gross R&D expenditure per GDP and its relative change over the last 10 years for three of the four income groups and 20 selected countries.
- Global average value of R&D expenditure per GDP and its relative change are 2.63 and 30%, respectively.
- Values for LMI and UMI countries tend to be horizontally dispersed from average group values, while there is a vertical dispersion across HI countries.
- Although LMI country values place on similar heights to the LMI group average, plots for Indonesia, Cambodia and Kenya deviate far to the right of the group average.
- Relative change in LMI, UMI and HI countries over the last 10 years is 3%, 62% and 25%, respectively.

Figure 14. Gross expenditure on R&D as a share of GDP in 2020, selected countries

Note: Average value of the LI group is not calculated due to low data availability. *Source:* Authors' elaboration.

42 Due to data limitations, recent and reference years vary across countries, and LI data is not included in this analysis.

Figure 15. **Gross expenditure on R&D as a share of GPD and its relative change, 2010-2020, selected countries**



Source: Authors' elaboration.

3) Transition path from LI to HI countries:

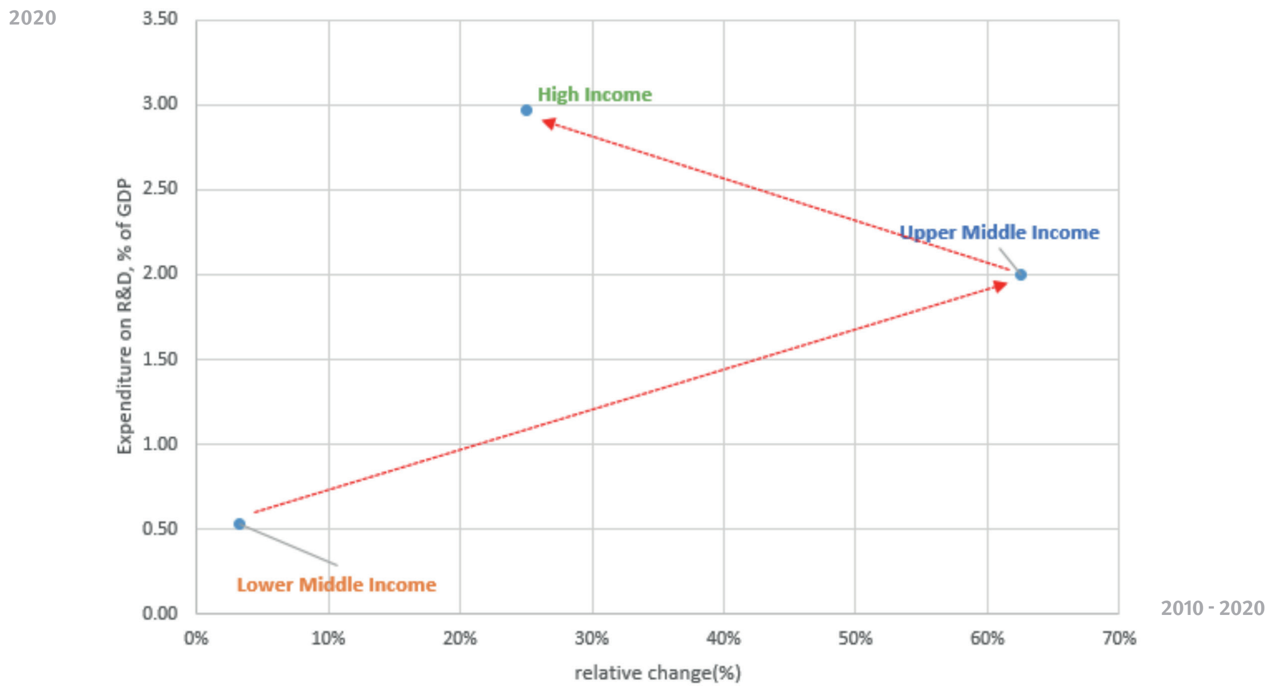
- While considering the lack of data for the LI average, the transition path of the indicator shows the counterclockwise direction, as shown in Figure 16.
- R&D expenditure and its growth rate for the UMI group are higher than those of the LMI group.
- Although R&D expenditure for the HI group is higher than the UMI group, its growth rate is lower than UMI since HI countries have already achieved a certain level of R&D investment.

4) Time series of gross expenditure on R&D as a share of GDP in RoK and China:

- The plotting graph in Figure 17 shows change of R&D expenditure per GDP in RoK and China between 1996 and 2020, during which both countries succeeded in industrialization.
- RoK R&D expenditure per GDP remained around 2% until 2000, then began to increase steadily, exceeding the HI average around 2010. RoK records the second-highest value after Israel.
- China's R&D expenditure per GDP was similar to the average of the LI group in 1996. However, it continued to increase steadily and exceeded the UMI average around 2015, and recorded a value higher than the UMI group average in 2020.

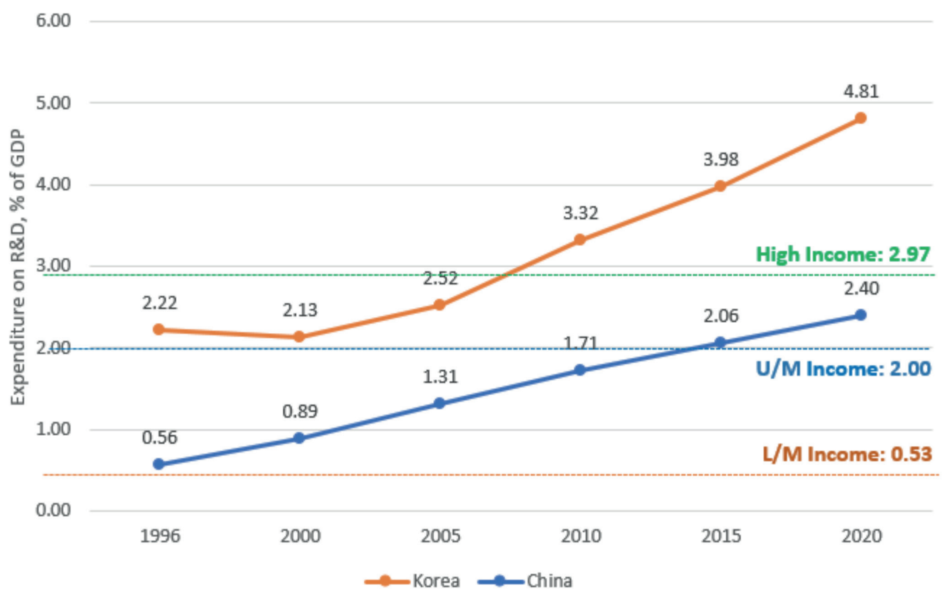
These findings are confirmed in in Box 5, which also shows the trend of the composition of expenditures in both the public and private sectors.

Figure 16. LI to HI transition path of gross expenditure in R&D as share of GDP, selected countries



Note: Average value of the LI group is not available due to low data availability. *Source:* Authors' elaboration.

Figure 17. Change in gross expenditure in R&D as share of GDP, RoK and China, 1996-2020



Source: Authors' elaboration.

Box 5. R&D investment trends, public vs private, RoK and China

Both RoK and China have witnessed a sudden increase in R&D inputs in terms of R&D expenditure as % of GDP. More importantly, the private sector rapidly overtook the public sector during each country's industrial upgrading, from the technology introduction stage to the technology internalization stage (in case of RoK, from around 1980, and China from around 2000). The trends in these two countries, therefore, indicate that developing countries should increase their efforts in terms of not only R&D investments as share of GDP but also the share of the private sector in R&D investments.

[R&D expenditure in RoK, 1971–2001]

	1976	1981	1986	1991	1996	2001
R&D expenditure/GDP	0.42	0.59	1.52	1.71	2.22	2.28
Public vs private ratio	64:36	42:58	19:81	19:81	26:74	27:73

[R&D expenditure in China, 1995–2019]

	1995	2000	2005	2010	2015	2019
R&D expenditure/GDP	0.57	0.90	1.32	1.76	2.07	2.23
Public vs private ratio	N/A	N/A	28:72	25:75	22:78	21:79

Source: Park et al. (2021).

IPR protection: Patent application by non-residents per million people.

1) Patent application by non-residents per million people in each income group:

In general, higher-income countries tend to have more non-resident patent applications per GDP than lower-income countries.

- Average value of the indicator in LI, LMI, UMI and HI countries is 1.95, 18.77, 89.56 and 560.88, respectively, as shown in Figure 18.
- The most significant increase among different income groups is observed between UMI and HI countries.

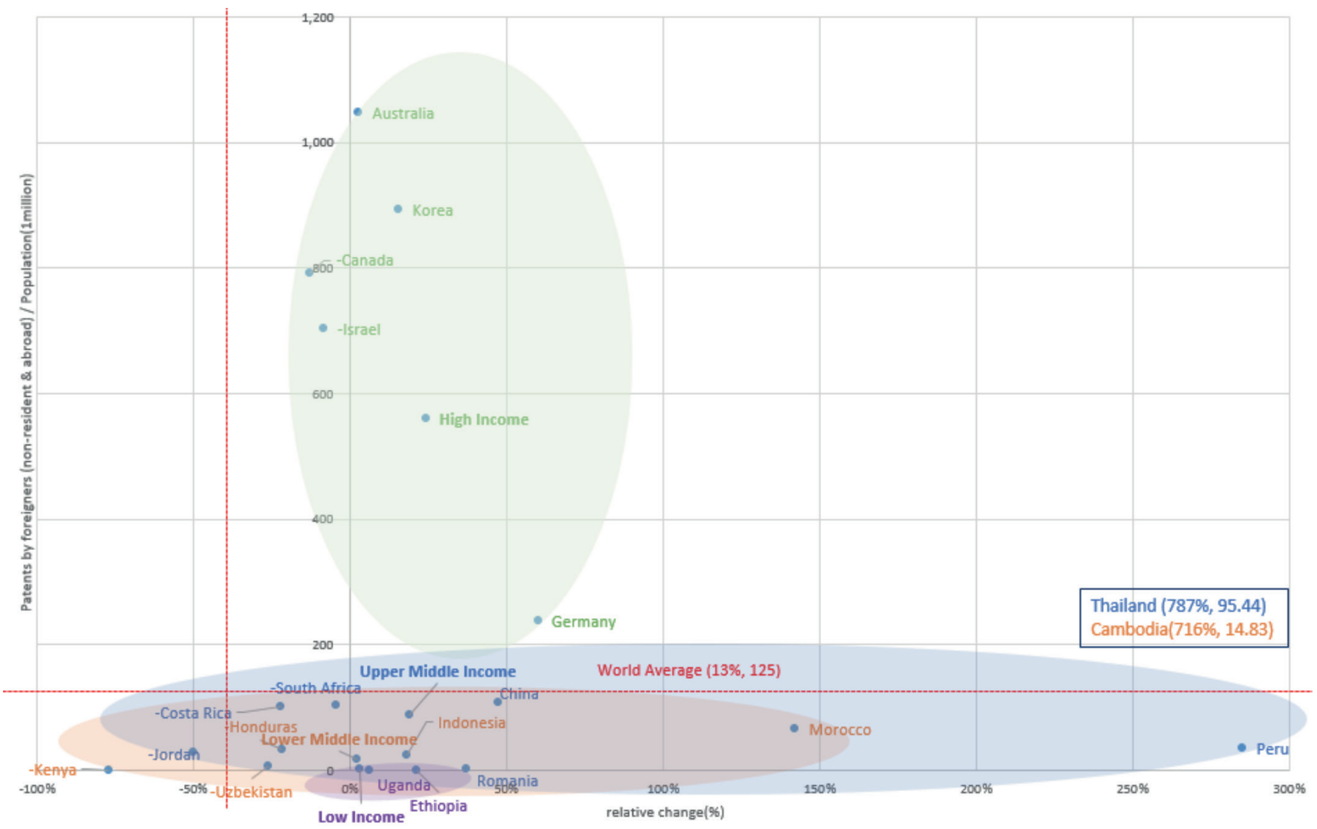
2) Patent applications by non-residents per million people and its relative change over the last 10 years:

- Figure 19 shows indicator values and their relative changes over the last 10 years for the four income groups and 20 selected countries.
- Global average of patent applications by non-residents per million people, and its relative change, are 125 and 13%, respectively.
- Values for the LI, LMI and UMI countries tend to be horizontally dispersed from the group average values in the figure, while there is a vertical dispersion among HI countries.

Figure 18. Patent applications by non-residents, per million people in 2020, selected countries

Source: Authors' elaboration.

Figure 19. Patent applications by non-residents, per million people, and the relative change 2010-2020, selected countries



Source: Authors' elaboration.

3) Transition path from LI to HI countries:

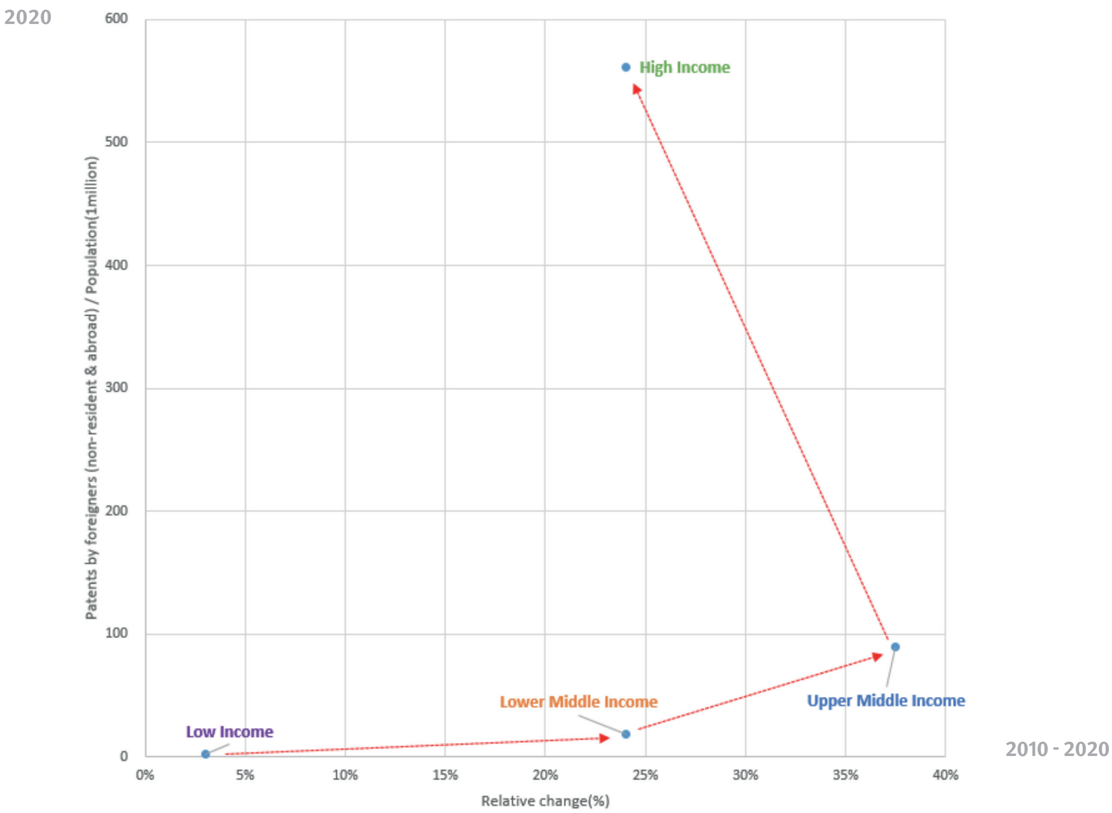
- The transition path has a shape of a counter-clockwise curve, as shown in Figure 20.
- Considering the average value and the growth rate of LI, LMI and UMI groups, patenting activities by non-residents tend to begin during the transition from the LMI to UMI stage. However, a meaningful level of patenting activities by non-residents occurs during the transition between the UMI and HI stages.
- This indicator becomes more prominent at the HI stage.

4) Time series of patent applications by non-residents per million people in RoK and China:

- The plotting graph in Figure 21 shows the change in patient applications in RoK and China between 1985 and 2020, the period during which both countries succeeded in industrialization.
- Patent applications by non-residents in RoK have been above the UMI average since 1985 and have increased at a rapid rate since then. After applications exceeded the HI average around 2000, they have increased at a slightly slower pace since 2005.
- Patent applications by non-residents in China were lower than the LMI average around 1985 yet have increased at a slow and steady pace since 1995, exceeding the UMI average after 2010.

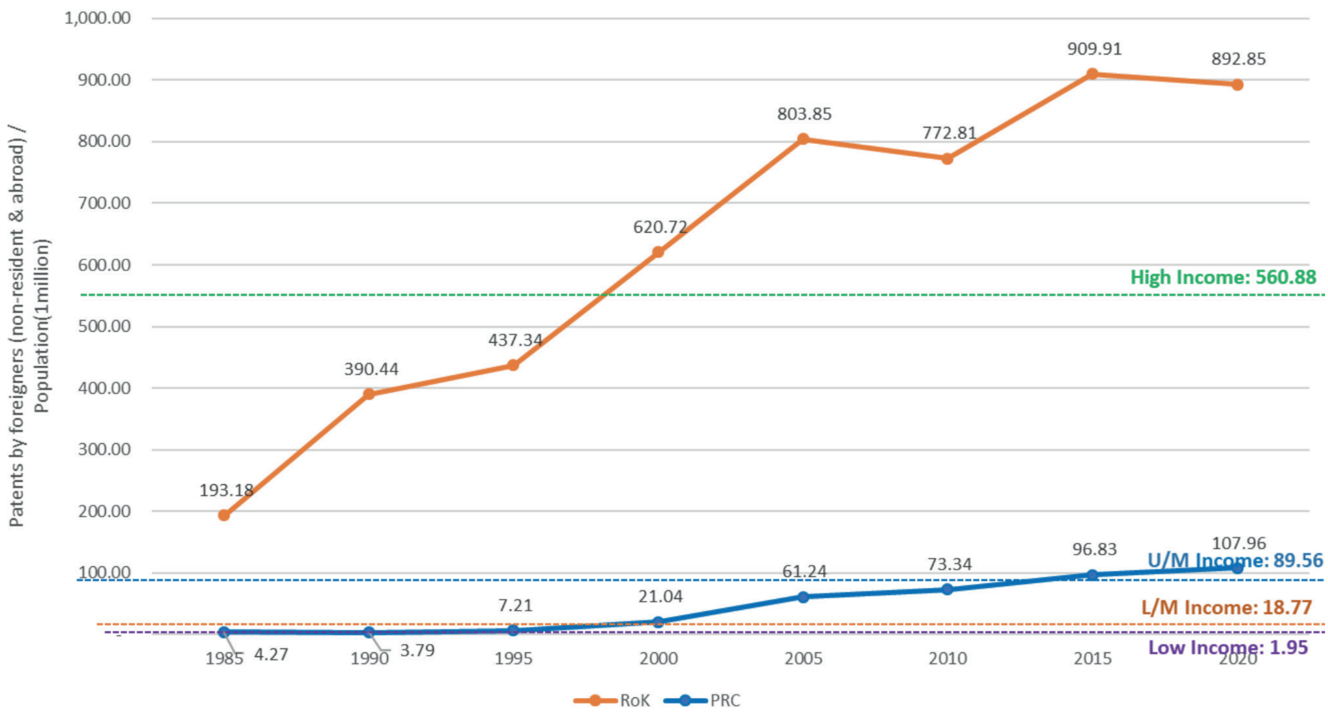
These findings are confirmed in Box 6, which also discusses trends in patenting activities by residents and non-residents.

Figure 20. LI to HI transition path of patent applications by non-residents per million people, selected countries



Source: Authors' elaboration.

Figure 21. Change in patent applications by non-residents per million people, RoK and China, 1985-2020



Source: Authors' elaboration.

Business: New business registrations per 1,000 people (ages 15-64).

1) New business registrations per 1,000 people of selected countries in each income group:

Higher-income countries tend to have higher new business density until the UMI stage; the HI average is lower than the UMI average.

- Average new business density in LMI, UMI and HI countries is 0.44, 6.30 and 4.60, respectively, as shown in Figure 22 (LI data is not available).
- As income increases from the LMI to the UMI stage, new business density significantly increases, from 0.44 to 6.30. However, it decreases to 4.60 for HI.
- Within the LMI group, Morocco, Uzbekistan and Kenya are all significantly higher than the average.
- Within the UMI group, South Africa registrations are significantly higher than the group average and the level of other countries.
- Within the HI group, registrations in Australia are significantly higher than the average.

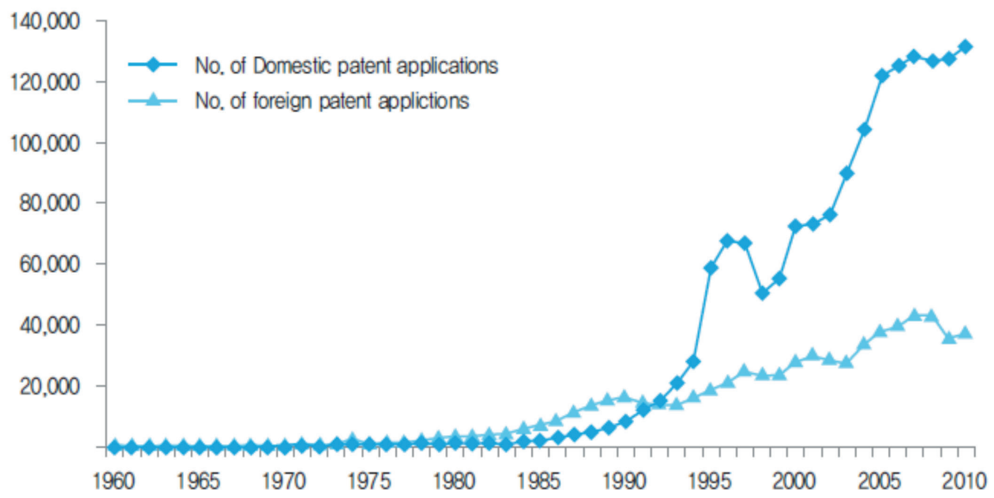
2) New business registrations per 1,000 people in RoK and China between 2006 and 2020:

- While the level of new business density is higher in China compared to RoK, it improves at much faster pace in China than in RoK, as shown in Figure 23.

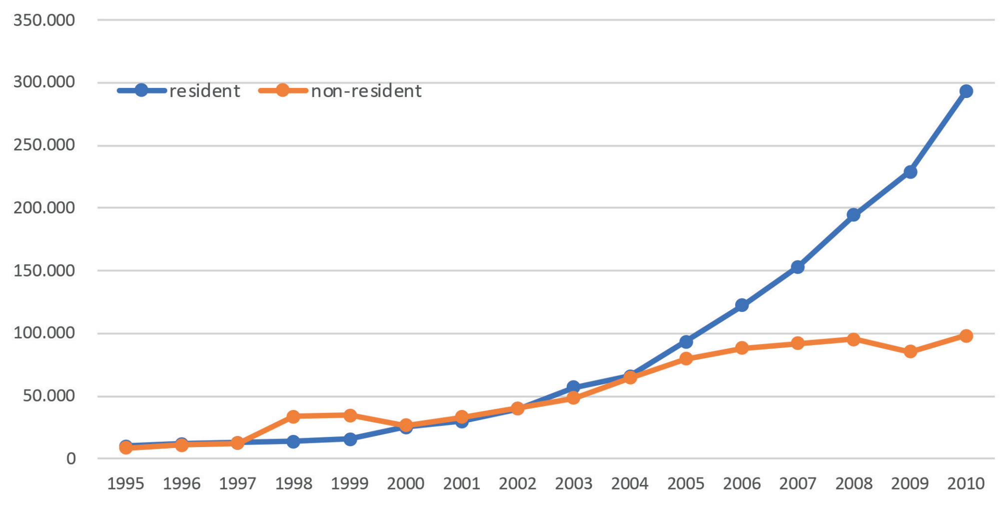
Box 6. Patent application trends, residents vs non-residents, during rapid industrialization in RoK and China

In RoK and China, patent applications by non-residents dominated when the two countries established their IPR regimes under international pressure. However, the short dominance of foreign patents was soon overshadowed by the rapid growth of patents by residents in both countries during their respective rapid industrialization periods.

[Patent applications by residents and non-residents in RoK, 1960-2010]

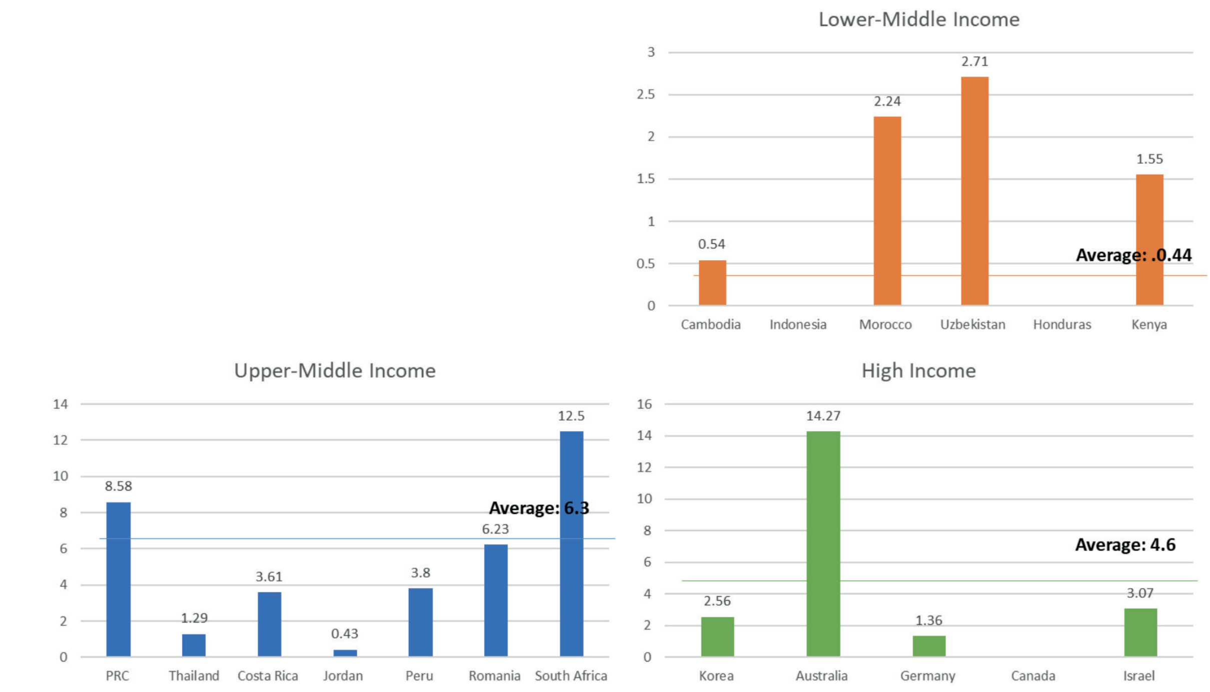


[Patent applications by residents and non-residents in China, 1995-2010]



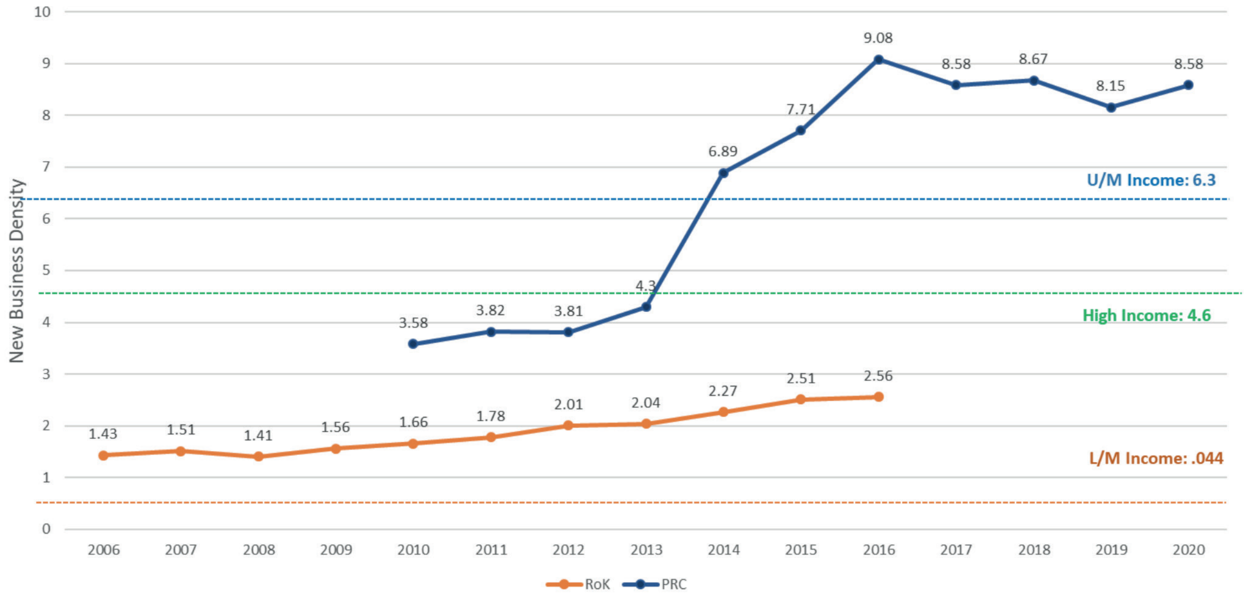
Source: Park et al. (2021).

Figure 22. New business registrations per 1,000 people ages 15-64, selected countries, 2006-2020



Note: Data for RoK and the HI average is from 2016 and 2018, respectively. *Source:* Authors' elaboration.

Figure 23. Change over time in new business registrations per 1,000 people ages 15-64, RoK and China



Source: Authors' elaboration.

Finance: Market capitalization of listed domestic companies, % of GDP.

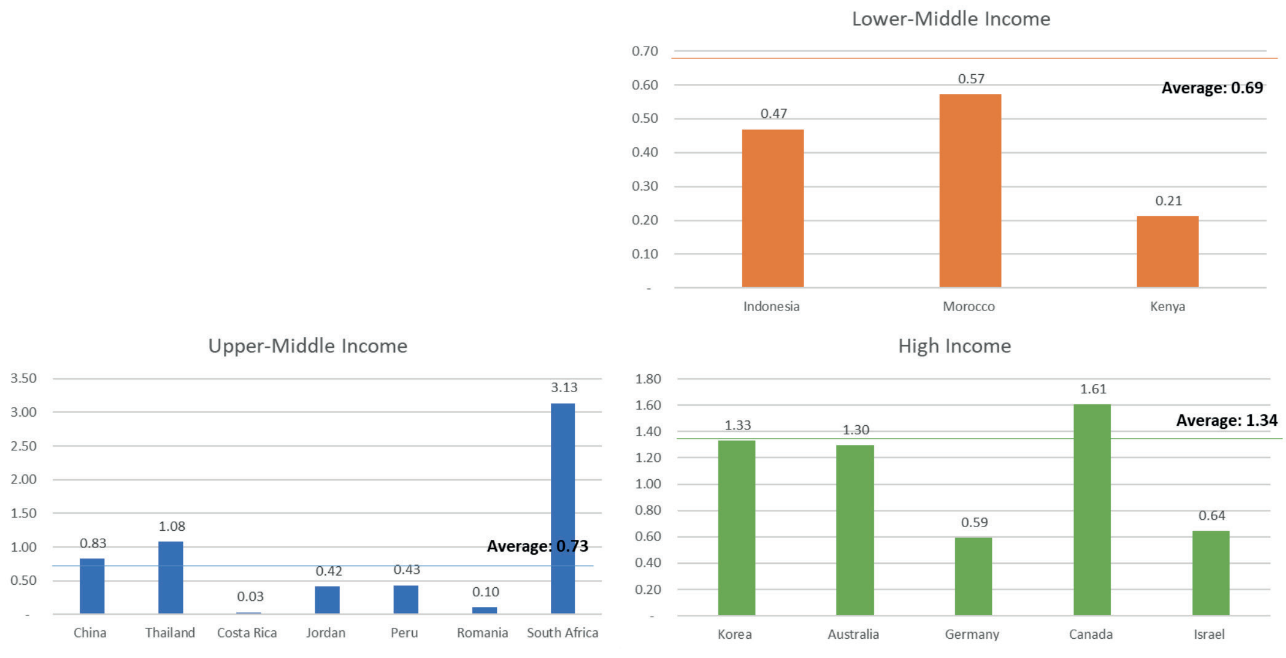
1) Market capitalization of listed domestic companies per GDP of selected countries in each income group:

- Average value of the indicator in LMI, UMI and HI countries is 0.69, 0.73 and 1.34, respectively, as shown in Figure 24. The LI average is not presented due to low data availability.
- As income increases, the average value of the indicator increases by 5.7% from LMI to UMI, and by 83% from UMI to HI.

2) Market capitalization of listed domestic companies per GDP and its relative change over the last 10 years:

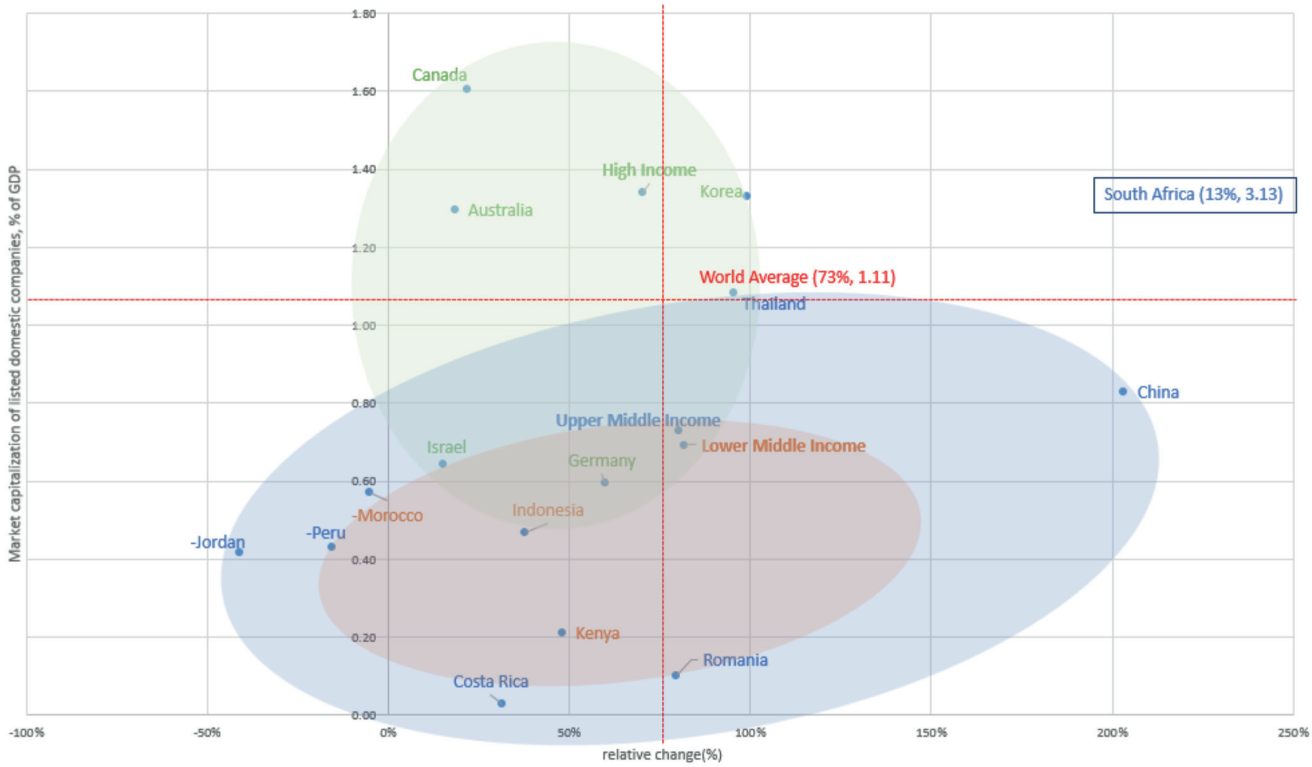
- Figure 25 shows the value of this indicator and its relative change over the last 10 years for three of the four income groups and 15 selected countries.
- Global average market capitalization and its relative change is 1.11 and 73%, respectively.
- Values for UMI countries are more sparsely dispersed than for other income groups and market capitalization of South Africa is far above the average of UMI group average.
- Market capitalization of HI countries is far beyond that of the other income countries and are vertically dispersed.

Figure 24. **Market capitalization of listed domestic companies, % of GDP in 2020, selected countries**



Note: Due to low data availability, LI countries are not included in the analysis. *Source:* Authors' elaboration.

Figure 25. Marketing capitalization of listed domestic companies, % of GDP, and the relative change from 2010-2020, selected countries



Source: Authors' elaboration.

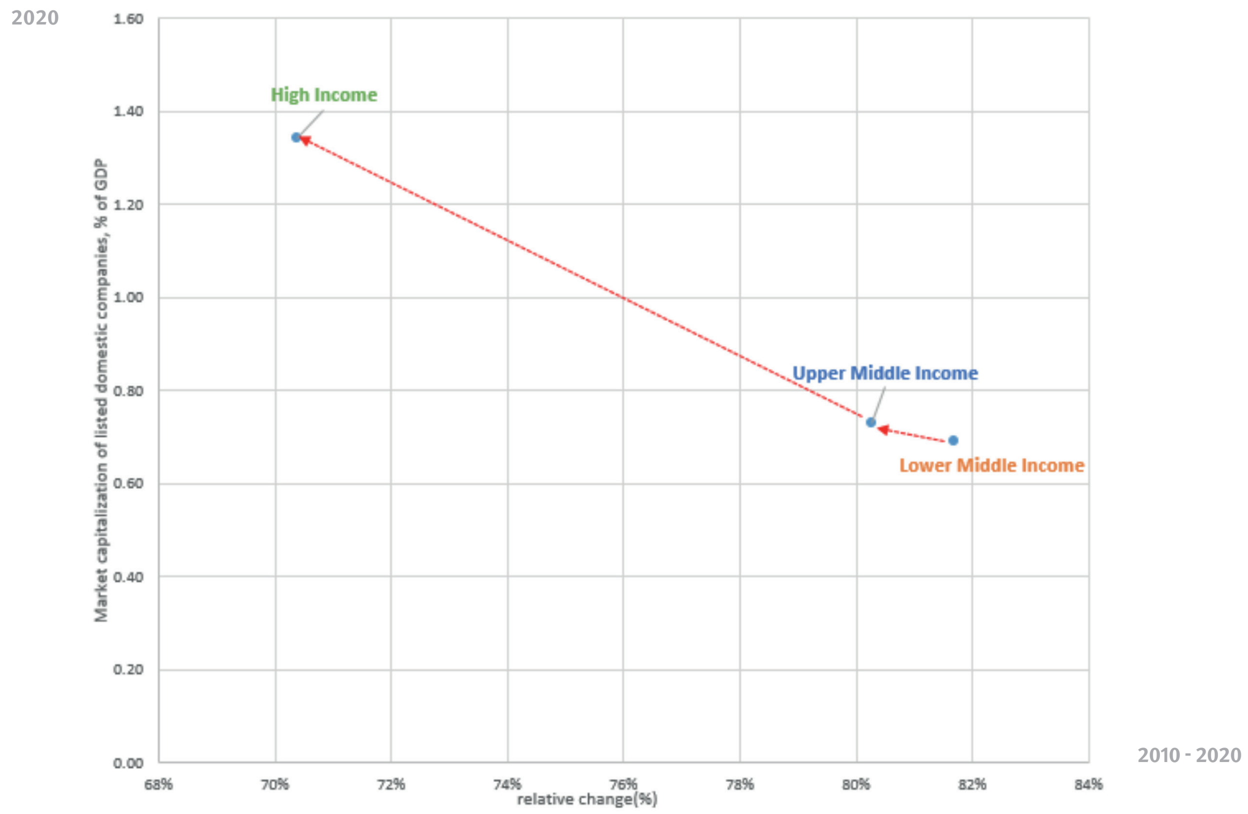
3) Transition path from LI to HI countries:

- The transition path demonstrates a left, upward direction, as shown in Figure 26.
- Average value of the indicator, and its relative change, for the LMI and UMI groups are similar, while the HI average value is much higher than that of other income groups.
- This indicator becomes more prominent at the HI stage.

4) Time series of market capitalization of listed domestic companies per GDP in RoK and China:

- The plotting graph in Figure 27 shows the change in value in RoK and China between 2005 and 2020.
- RoK's market capitalization reached the HI stage only recently despite its success in industrial upgrading.
- In the case of China, the value of the indicator increased rapidly and reached close to the LMI average by 2010. Afterwards, it has increased at a slower pace.

Figure 26. LI to HI transition path for market capitalization of listed domestic companies, % of GDP, selected countries



Source: Authors' elaboration.

Figure 27. Change in market capitalization of listed domestic companies, % of GDP, RoK and China, 2005-2020

Source: Authors' elaboration.

4.2.3 Reflexivity: Interaction (network)

Production: Share of firms exporting directly/indirectly (at least 10% of sales).

World Bank Enterprise Survey data has some limitations, as the survey is not conducted every year and for a large number of countries. Some of the 20 countries in our analysis are not included in the survey. Therefore, only the column chart and scatter plot graph with a trendline are displayed for this indicator.

1) Share of firms exporting directly/indirectly (at least 10% of sales) of selected countries in each income group:

Figure 28 confirms the assumption that higher-income countries have a larger share of firms exporting directly/indirectly than lower-income countries.

- Average shares of firms exporting directly/indirectly in LI, LMI, UMI and HI countries are 11%, 13%, 15%, and 24% respectively.
- As income increases, the change in share of firms exporting directly/indirectly from LI to LMI countries increase by only 2%, whereas the increase from LMI to UMI is also 2%. However, from UMI to HI countries, the share jumps from 15% to 24%, increasing by 9%.
- Morocco, LMI group, and Jordan, a UMI country, show the highest share of firms exporting directly/indirectly among the four income groups and selected countries.

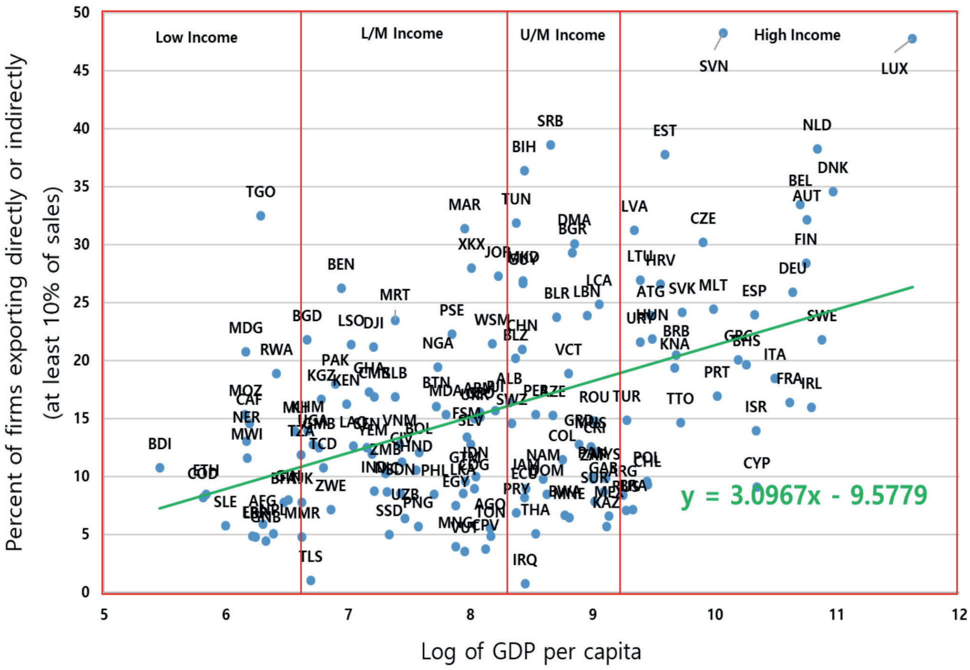
2) Share of firms exporting directly or indirectly and per capita GDP:

- Using data covering 153 countries, the scatter plotting in Figure 29 shows the positive correlation between GDP per capita and share of firms exporting directly/indirectly. Still, there is considerable variation within income groups.
- The equation of the trendline can be expressed as $Y = 3.0967X - 9.5779$

Figure 28. Share of firms exporting directly/indirectly (at least 10% of sales) in 2019, selected countries

Note: Among HI countries, only data from Israel is available. *Source:* Authors' elaboration.

Figure 29. Share of firms exporting directly/indirectly and GDP per capita, selected countries



Source: Authors' elaboration.

Technology: Intellectual property payments per million GDP.

1) Intellectual property payments (BoP, current US$) per million GDP of selected countries in each income group:

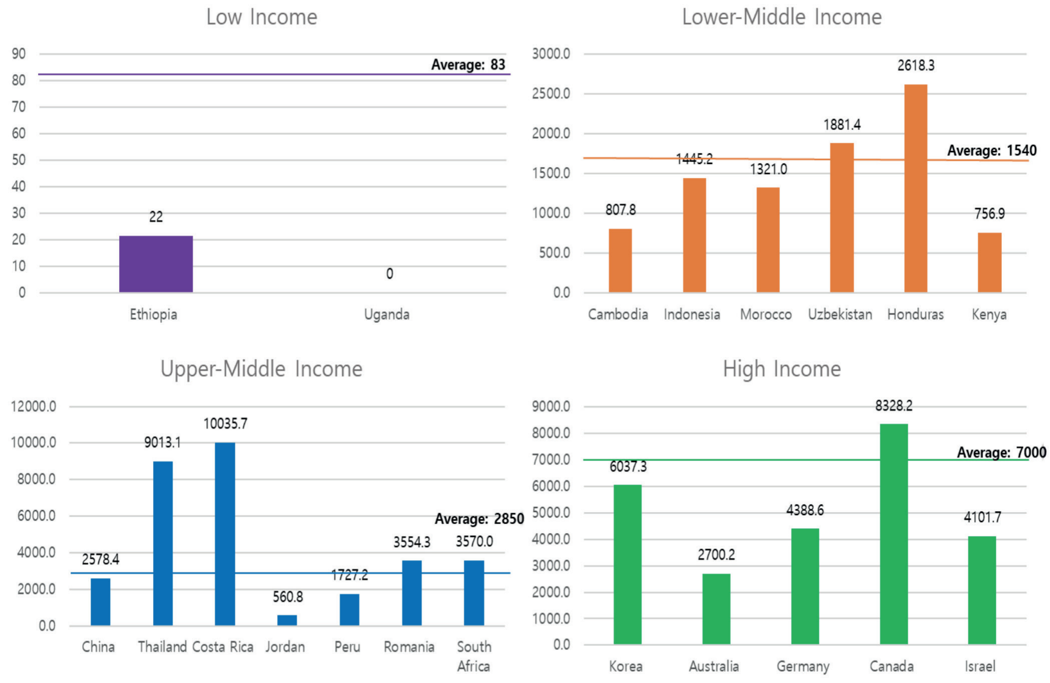
Higher-income countries tend to have higher intellectual property payments than low-income countries, as shown in Figure 30. This confirms the assumption and supports the validity of this indicator.

- Average intellectual property payments in LI, LMI, UMI and HI countries are 83, 1,540, 2,850, and 7,000 per million GDP, respectively.
- As income increases, the growth rate of intellectual property payments from LI to LMI countries increases by 1,755%; from LMI to UMI, by 85%; and from UMI to HI countries, by 145%.
- The UMI countries Costa Rica and Thailand have the highest intellectual property payments compared to other countries.

2) Intellectual property payments (BoP, current US$) per million GDP and their relative change over the last 10 years (2010-2020):

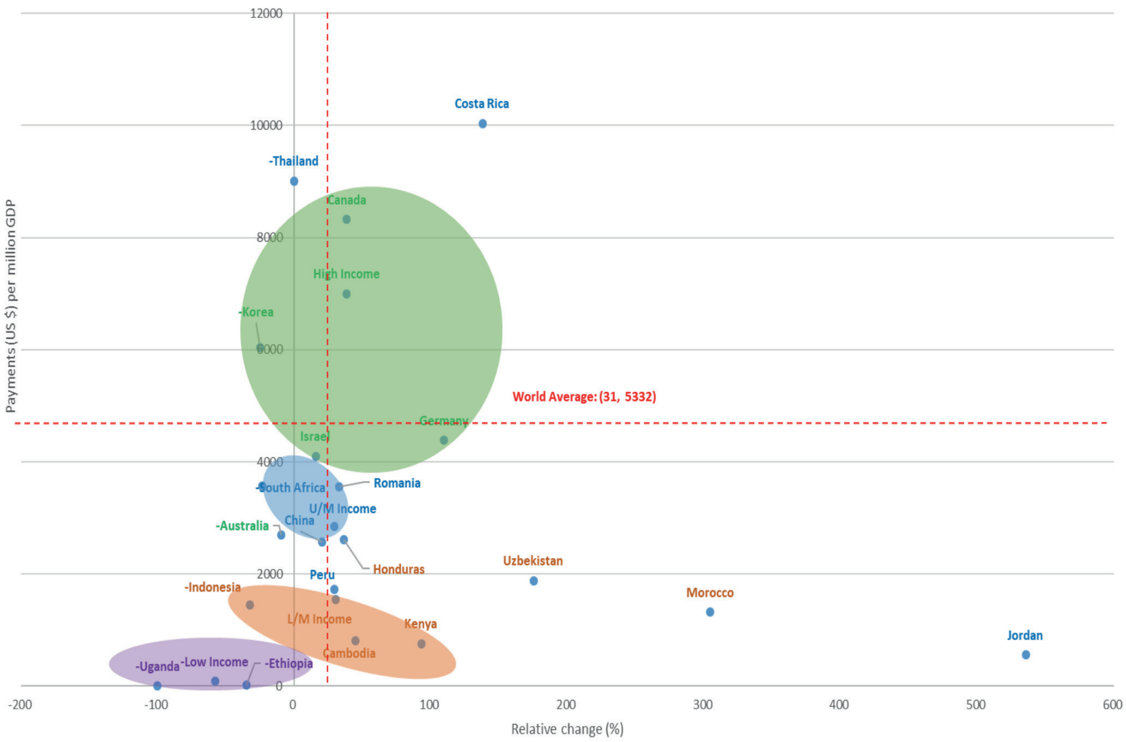
- Figure 31 shows the intellectual property payments per million GDP and its relative changes over 2010-2020 for the four income groups and 20 selected countries.
- Global payments per million and the relative change in payments is $5,332 per million GDP and 31%, respectively.
- LI and HI countries generally do not deviate from the group average, while there is large variation across LMI and UMI countries.
- Jordan deviates further from the UMI average, indicating that its relative change has significantly increased over the last six years.
- Morocco and Uzbekistan deviate from the average LMI value, indicating that their relative changes have increased considerably over the last 10 years.

Figure 30. Intellectual property payments per million GDP in 2020, selected countries



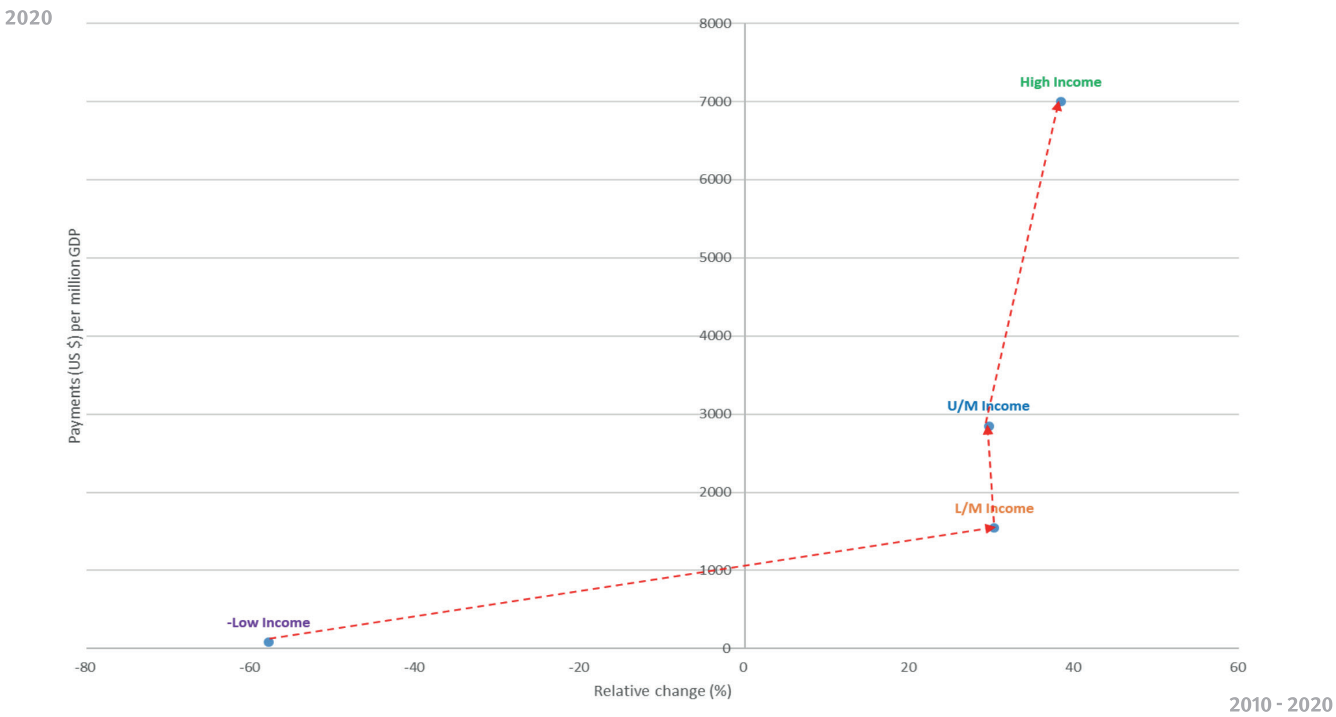
Source: Authors' elaboration.

Figure 31. Intellectual property payments per million GDP, and their relative change, 2010-2020, selected countries



Source: Authors' elaboration.

Figure 32. LI to HI transition path of intellectual property payments per million GDP, selected countries



Source: Authors' elaboration.

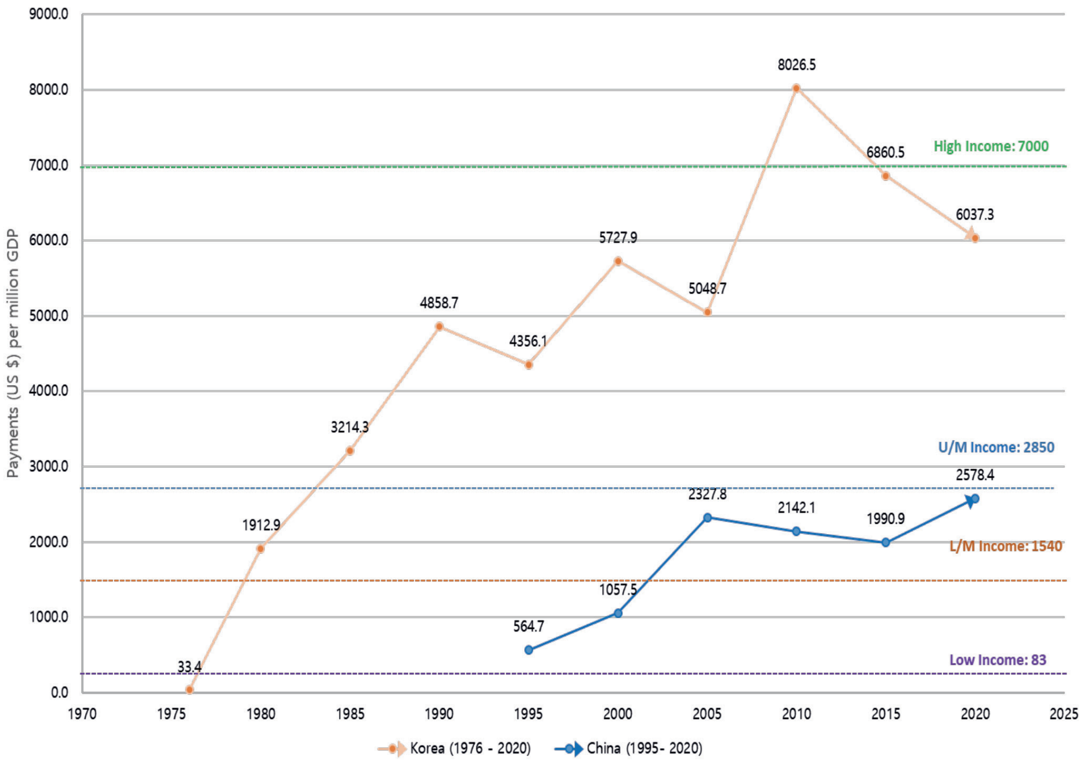
3) Transition path from LI to HI countries:

- The overall transition path follows in a counterclockwise direction, similar to an exponential growth curve, as shown in Figure 32.
- While the highest improvement in relative change occurs between LI and LMI groups, the highest increase occurs between UMI and HI groups.
- Unlike other indicators, where the relative change stagnates when countries reach the HI stage, here, the relative change of the HI group is higher than those of the LMI and UMI groups.

4) Time series of intellectual property payments (BoP, current US$) per million GDP in ROK and China:

- Data for RoK (1976-2020) and China (1995-2020) is shown in Figure 33.
- In RoK, payments increased significantly from 1976 to 1990 and from 2005 to 2010, when they began decreasing.
- In China, payments increased significantly until 2005 and have stagnated since then.

Figure 33. Change over time in intellectual property payments per million GDP, RoK and China



Source: Authors' elaboration.

Box 7 shows the historical trend of technology balance of payments in the RoK over the course of its industrialization.

Box 7. Technology balance of payments trends in RoK during the industrialization period

As both technology exports and imports in RoK have been rapidly increasing during the country's industrial upgrading, two points deserve to be noted. By the time RoK entered into its technology creation stage beginning in the late 1990s, its technology balance of payment began to improve rapidly. Even during the technology creation stage, however, the role of technology imports has not diminished. This underscores the importance of external sourcing of new knowledge and the necessity of interactions for innovations.

[Technology balance of payments (US$ millions) in RoK, 1981-2019]

	1981	1986	1991	1996	2001	2006	2011	2016	2019
Technology export (A)	11.8	11.7	35.2	108.5	619.1	1,897	4,032	10,687	13,756
Technology import (B)	107.1	411.0	1,183.8	2,297.2		4,838	9,900	14,842	17,876
Technology balance of payment (A/B)	0.11	0.03	0.03	0.05	0.23	0.39	0.41	0.72	0.77

Source: Korea Industrial Technology Association (2020).

Source: Park et al. (2021).

Figure 34. **International co-authored scientific articles per 100,000 people in 2021, selected countries**

Source: Authors' elaboration.

Science**:** International co-authored scientific articles per 100,000 people.

Higher-income countries have a higher tendency to have international co-authored scientific articles than lower-income countries, as shown in Figure 34. This confirms the assumption for this indicator.

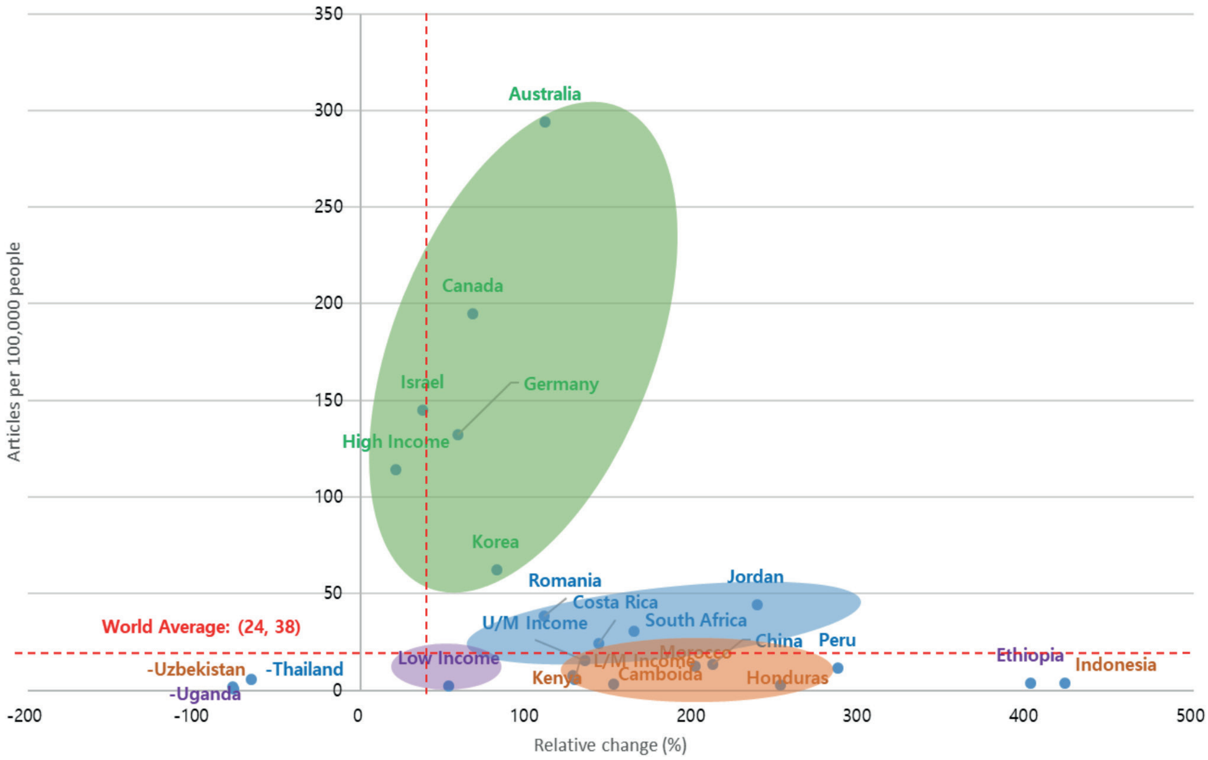
1) International co-authored scientific articles per 100,000 people of selected countries in each income group:

- Average international co-authored scientific articles in LI, LMI, UMI and HI countries are 2, 6, 16, and 114 per 100,000 people, respectively.
- As income increases, articles increase: from LI to LMI countries increases by 200%; from LMI to UMI countries, by 166%; and from UMI to HI countries, by 613%.
- Australia has the highest (294 per 100,000 people) among the selected HI countries, exceeding the group average.

2) International co-authored scientific articles per 100,000 people and their relative change over the last 10 years (2011-2021):

- Figure 35 shows the indicator and its relative change over 2011-2021 for the four income groups and 20 selected countries.
- Global average articles and the relative change over the last 10 years is 38 per 100,000 people and 24%, respectively.
- There is large variation within LI and LMI countries in terms of relative change, while there is large variation in HI countries in terms of the number of articles.
- Values for Ethiopia and Indonesia deviate far to the right of their income group average in the figure, indicating that their relative changes have increased considerably over the last 10 years. By contrast, values for Uzbekistan and Uganda are far to the left of their income group average, indicating that their relative changes have decreased considerably over the last 10 years.
- Over the last 10 years, the relative change in LI is 58%; in LMI, 129%; UMI, 129%; 134%; HI, 21%.

Figure 35. International co-authored scientific articles per 100,000 people and their relative change, 2011-2021, selected countries



Source: Authors' elaboration.

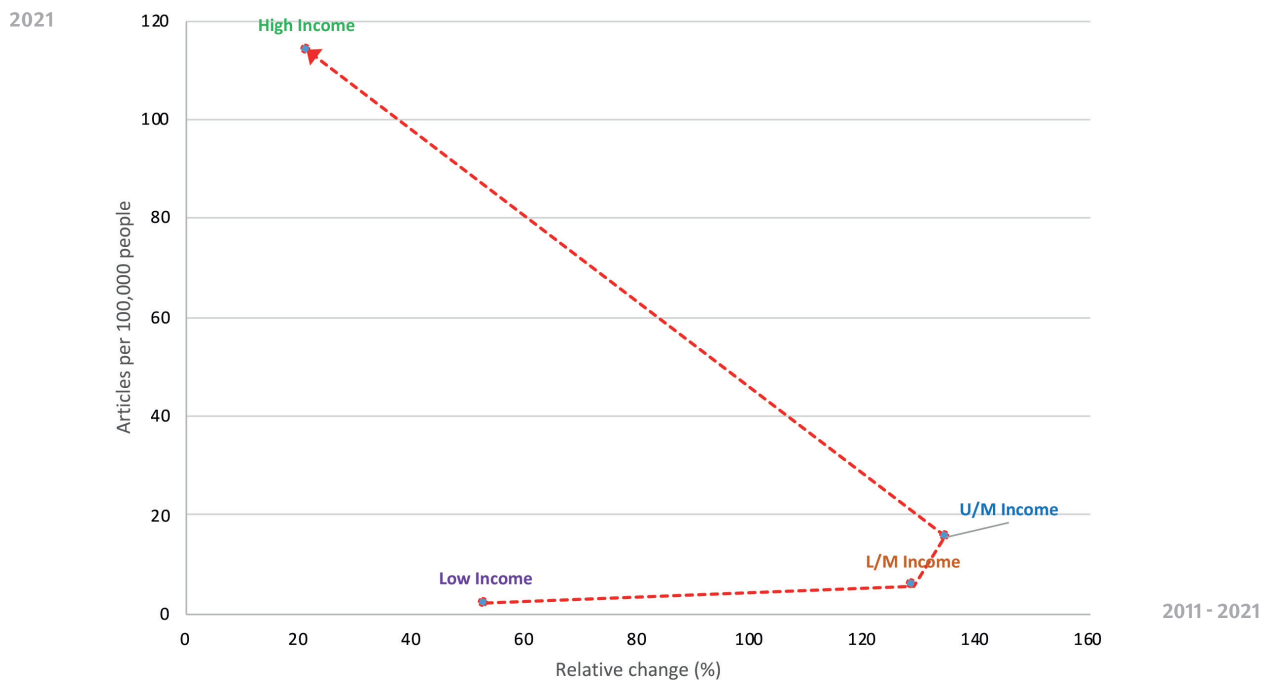
3) Transition path from LI to HI countries:

- As shown in Figure 36, the overall transition path follows a typical counterclockwise direction.
- While the growth rate in articles is significant between LI and LMI groups, the number of articles increases significantly between UMI and HI groups.

4) Time series of international co-authored scientific articles per 100,000 people in ROK and China:

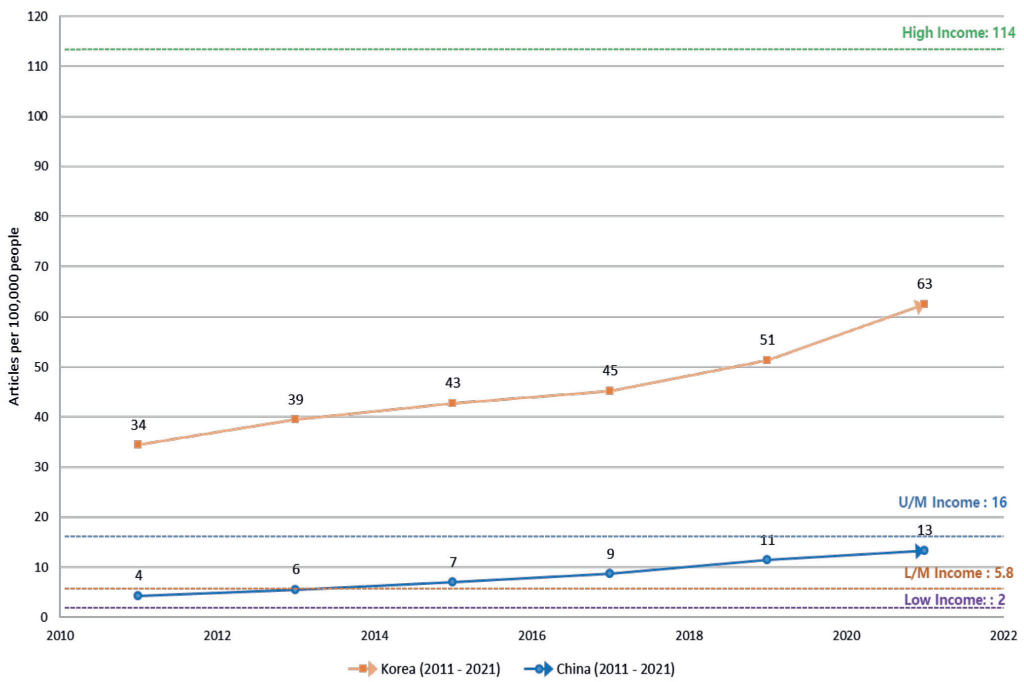
- Plotting data for RoK and China (2011-2021) is shown in Figure 37.
- In RoK ,international co-authored scientific articles have increased steadily since 2011 and significantly over the last three years.
- In China, the number of articles has increased steadily since 2011.
- However, values for both RoK and China are below their respective income group averages, indicating that they lack interactions with the international scientific community.

Figure 36. LI to HI transition path of international co-authored scientific articles per 100,000 people, selected countries



Source: Authors' elaboration.

Figure 37. Change in international co-authored scientific articles per 100,000 people, RoK and China, 2011-2021



Source: Authors' elaboration.

4.2.4 Reflexivity: Actors and capabilities

Production (capacity): Gross fixed capital formation as % of GDP.

1) Gross fixed capital formation as % of GDP of selected countries in each income group:

- Average gross fixed capital formation as % of GDP in LI, LMI, UMI and HI countries are 25.27, 25.31, 34.34 and 22.29, respectively, as shown in Figure 38.
- As income increases, average value increases from LI to UMI, yet the average value for HI countries is below the averages of other income groups.
- Within each income group, there are significant differences among countries. For example, the share of fixed capital formation in China is relatively high compared to other UMI countries, which should be carefully considered with interpretation.

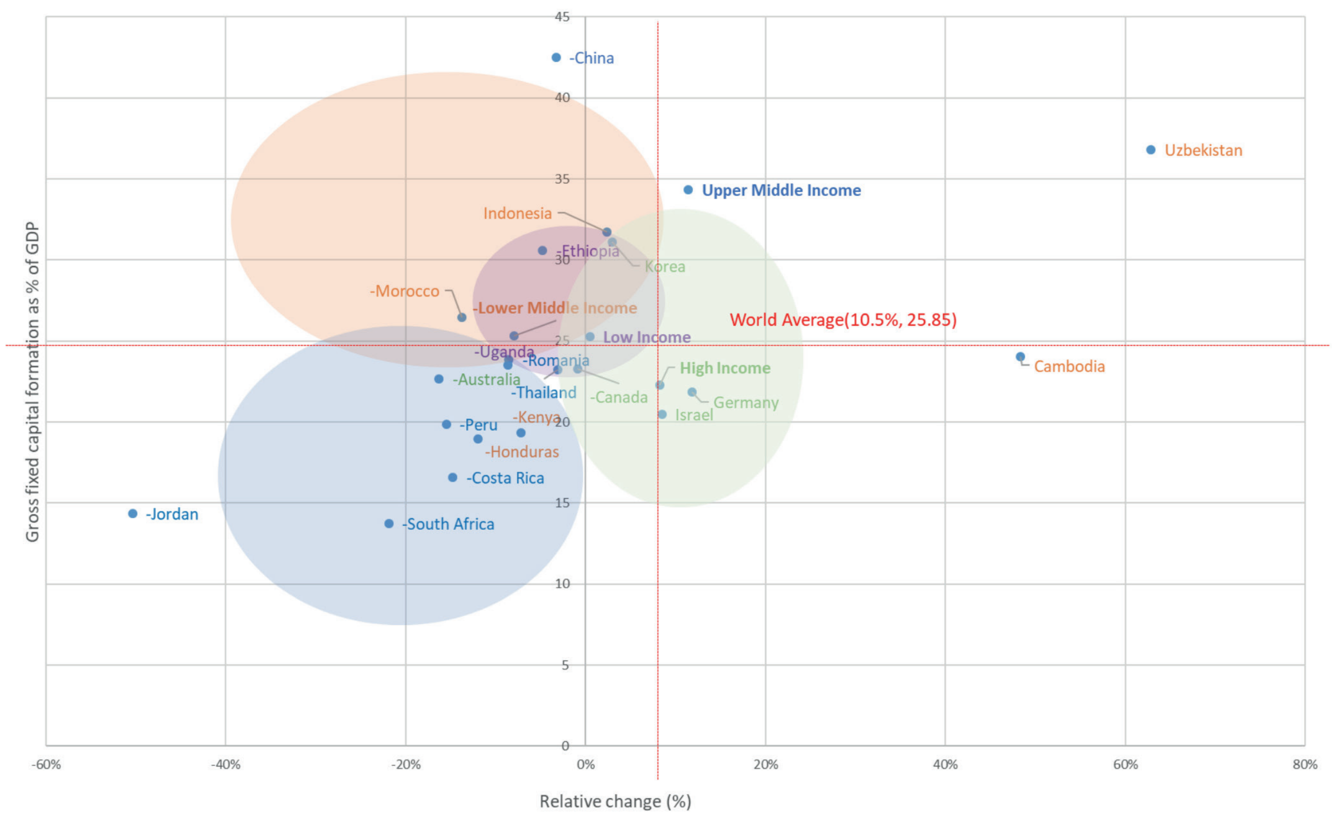
2) Gross fixed capital formation as % of GDP and its relative change between 2010 and 2020:

- Figure 39 shows the indicator and its relative changes over the past 10 years for the four income groups and 20 selected countries.
- The global average and its relative change are 25.85% and 10.5%, respectively.
- China is positioned far above other UMI countries and, as a result, the UMI average is located between that of China and other countries.
- Between 2010 and 2020, the relative change in LI, LMI, UMI and HI countries is -0.5%, -7.92%, 11.42% and 8.28%, respectively,

Figure 38. Gross fixed capital formation as % of GDP in 2020, selected countries

Source: Authors' elaboration.

Figure 39. Gross fixed capital formation as % of GDP and its relative change, 2010-2020, selected countries



Source: Authors' elaboration.

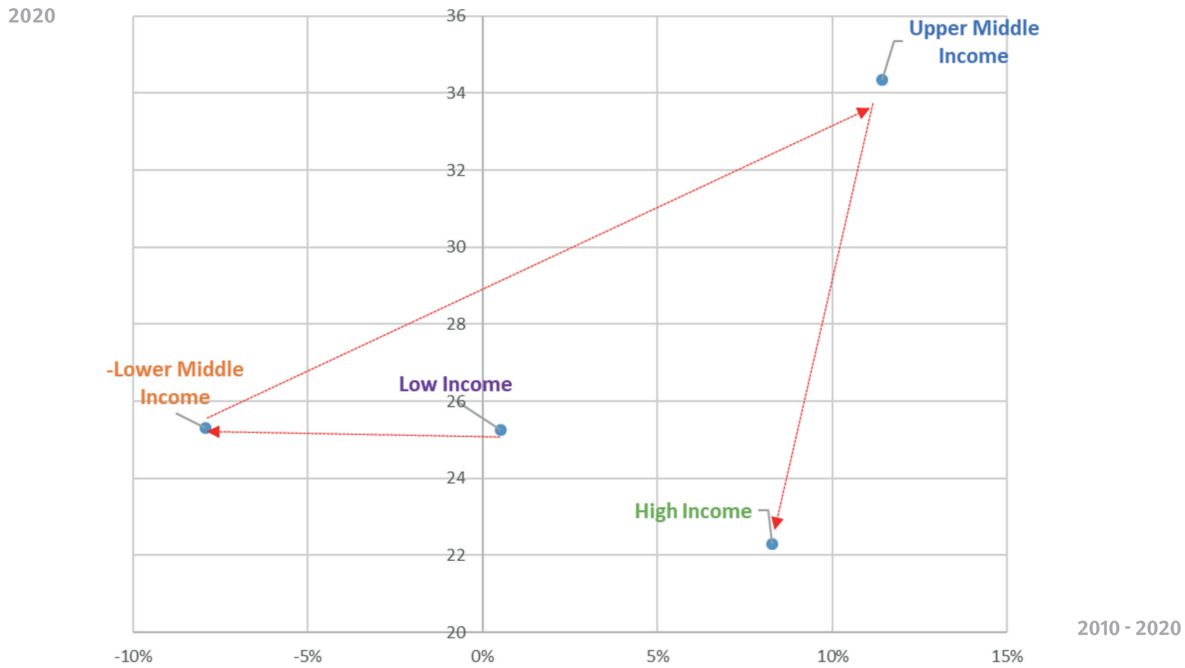
3) Transition path from LI to HI countries:

- As shown in Figure 40, the transition path proceeds left from LI to LMI, then right and upwards to UMI and drops downward from UMI to HI.
- An increase of fixed capital formation and its relative growth can be observed between LMI and UMI.
- There is a significant decrease between UMI and HI in terms of gross fixed capital formation, but its relative change drops on a smaller scale.

4) Time series of gross fixed capital formation as % of GDP in RoK and China

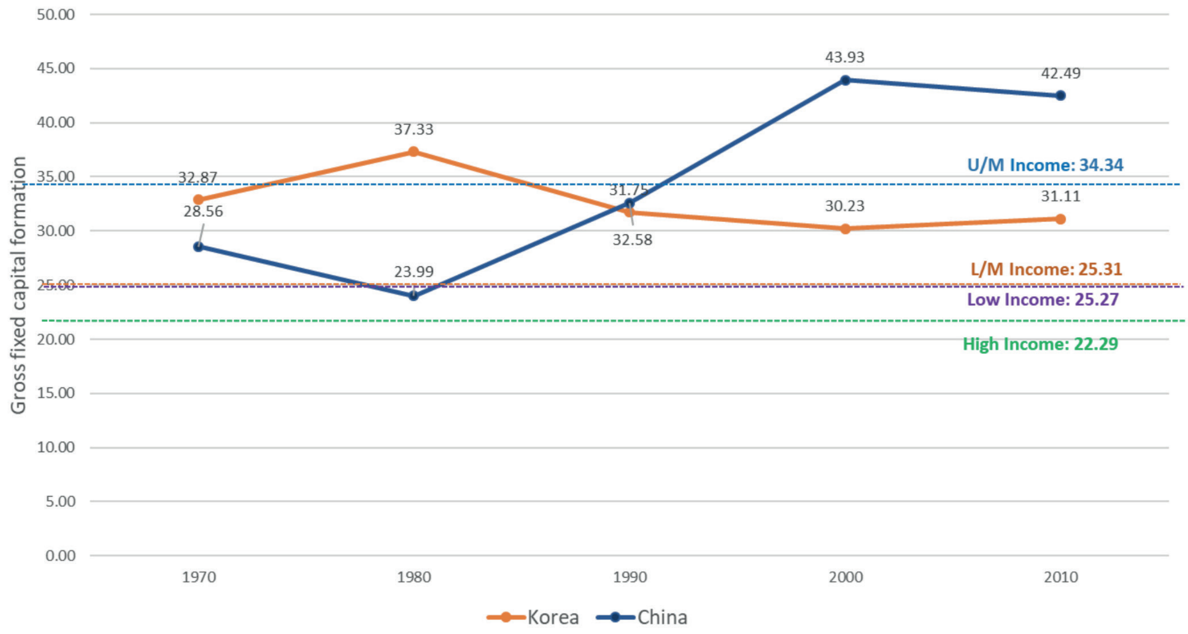
- The plotting graph in Figure 41 shows the historical change of gross fixed capital formation in RoK and China between 2000 and 2020, the period during which both countries experienced successful industrialization.
- The historical path of the RoK shows a v-shaped curve, which is consistent with the transition path shown in Figure 40. Gross fixed capital formation in RoK reached its peak around early 1990s, and since then has decreased at a slow pace.
- The level of gross fixed capital formation in China has continuously increased over time. It does not seem to have peaked, which is also consistent with the overall transition path as China belongs to the UMI group.

Figure 40. LI to HI transition path in gross fixed capital formation as % of GDP, selected countries



Source: Authors' elaboration.

Figure 41. Change in gross fixed capital formation as % of GDP, RoK and China, 1970-2020



Source: Authors' elaboration.

***Production (quality)*:** ISO 9001 certificates per 1,000 people.

International Standard Organization (ISO) Survey provides the data for the updated quality management system "ISO 9001:2015", which covers 194 countries for the three-year period 2018-2020. Thus, only the column chart and scatter plot with a trendline are displayed for this indicator.

1) The number of ISO 9001 certificates per 10 million people of selected countries in each income group:

Higher-income countries tend to have more ISO 9001 quality management systems certificates than lower-income countries, as shown in Figure 42. This confirms the assumption for this indicator.

- Average number of ISO 9001certificates in LI, LMI, UMI and HI countries is 10, 183, 1,727, and 3,402 per 10 million people, respectively.
- As income increases, the number of ISO 9001 certificates increases: from LI to LMI countries, the number increases by 1,730%; from LMI to UMI, by 843%; and from UMI to HI countries, by 97%.
- Israel has the highest number of ISO 9001 certificates (8,953 per 10 million people) among the selected HI countries, exceeding the group average.
- The noticeable UMI country is Romania, with 5,159 certificates per 10 million people.
- Overall, there is large variation among countries within the same income group.

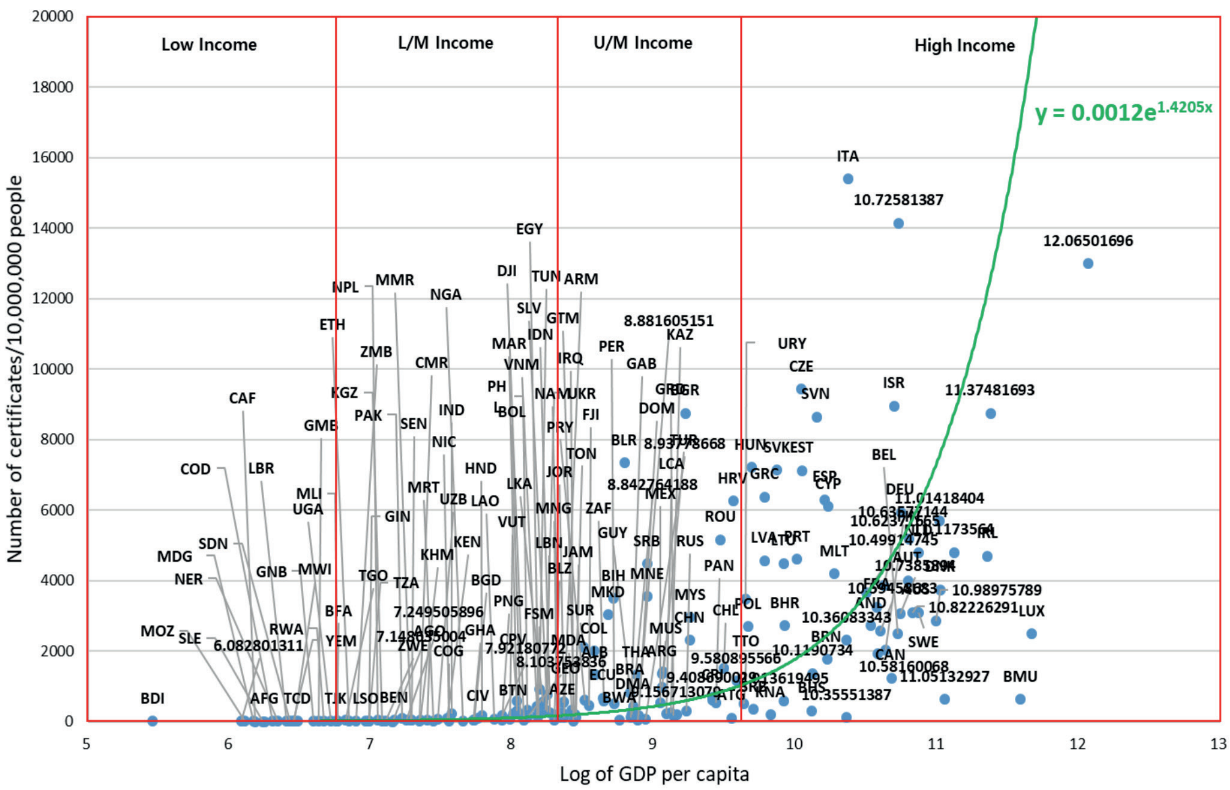
2) The number of ISO 9001 certificates per 10 million people and per capita GDP:

- Using the data for 179 countries, the scatter plotting in Figure 43 shows that the two variables, GDP per capita and the indicator, are exponentially correlated.
- Compared to LI and LMI countries, there is larger variation in UMI and HI countries, indicating that the number of ISO 9001 certificates increases sharply as income level transitions from UMI to HI countries.
- The equation of the trendline can be expressed as $Y = 0.0012e^{1.4205x}$

Figure 42. ISO 9001 certificates per 10 million people in 2020, selected countries

Source: Authors' elaboration.

Figure 43. ISO 9001 certificates per 10 million people and per capita GDP, selected countries



Source: Authors' elaboration.

Technology: Patent applications by residents, per 1 million people.

As shown in Figure 44, higher-income countries tend to have more patent applications by residents per 1 million people than lower-income countries, which implies that higher-income countries have more technological capability than lower-income countries. These results support the validity of this indicator.

1) Patent applications by residents per 1 million people in selected countries in each income group:

- Average patent applications by residents per 1 million people in LI, LMI, UMI and HI countries is 0.90, 12.73, 551.53 and 715.22, respectively.
- As income grows, average patent applications by residents increases: from LI to LMI, by 1,314%; from LMI to UMI, by 4,232%; and from UMI to HI, by 29%.
- Within the LI group, Ethiopia and Uganda record values below the average. Within the LMI group, all selected countries are below the average, while Cambodia and Honduras are even lower than the average of the LI group.
- In the UMI group, China records a remarkably high value, raising the group's average and making other UMI countries far below the average. A similar effect is observed with RoK in the HI group.

2) Patent applications by residents per 1 million people and their relative change over the last 10 years:[43]

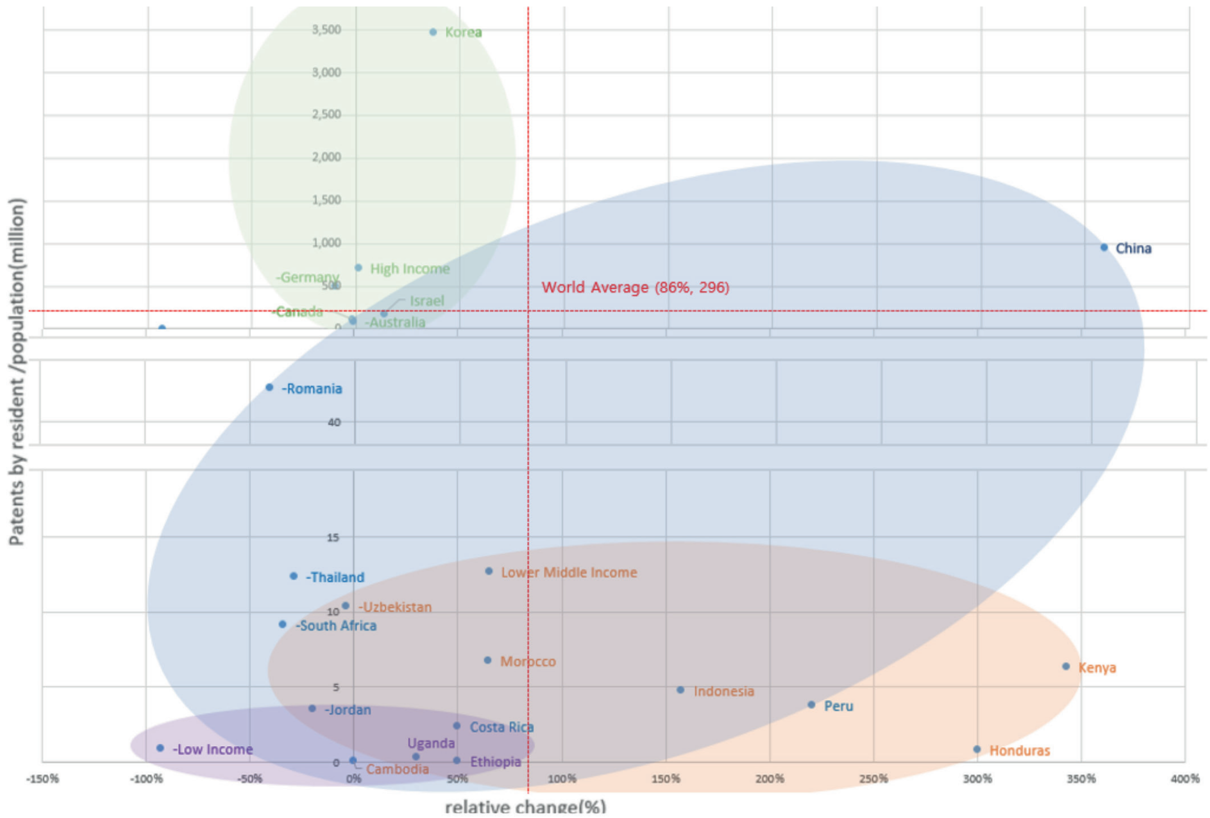
- Figure 45 illustrates the values and their relative changes over the last 10 years for the four income groups and 20 selected countries.
- The global average value of patent applications by residents per 1 million people, and their relative changes, are 296 and 86%, respectively.
- Values for LI and LMI countries are horizontally dispersed throughout the figure, while values for UMI countries are widely dispersed. Values for HI countries are far beyond those of the other income groups and are vertically dispersed.
- China and RoK record significantly higher values and growth rates than the average values of their respective income groups.
- Over the last 10 years, the relative change in patents by residents in LI, LMI, UMI and HI countries is -93%, 64%, 308% and 1%, respectively.

Figure 44. Patent applications by residents per 1 million people in 2020, selected countries

Source: Authors' elaboration.

43 Due to data limitations, recent and reference years vary across countries in this analysis.

Figure 45. Patent applications by residents per 1 million people and their relative change, 2010-2020, selected countries



Source: Authors' elaboration.

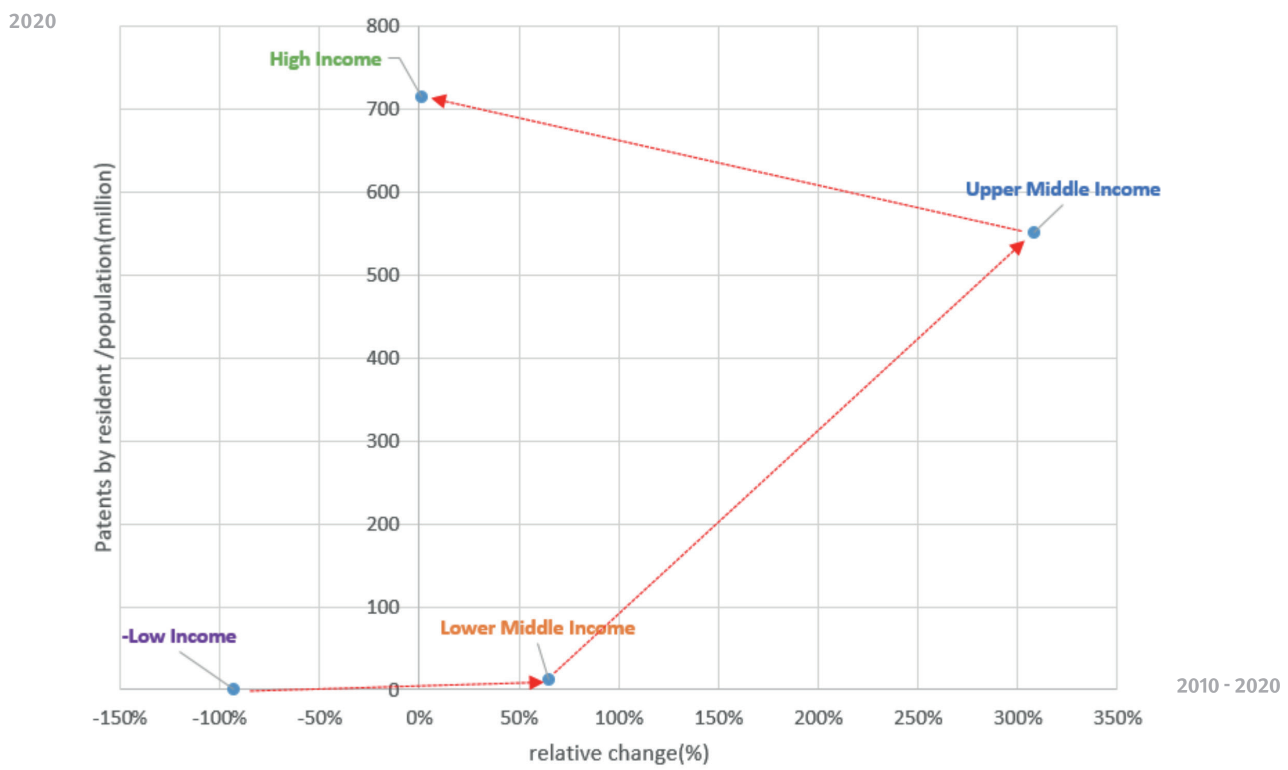
3) Transition path of patent applications by residents from LI to HI countrie:s

- The transition path follows the counterclockwise direction, as shown in Figure 46.
- While the average patent applications by residents of LI and LMI groups is similar, the average growth rate of LMI countries is higher than that of the LI group.
- Both the value of the indicator and its relative change significantly increases from LMI to UMI groups.
- For HI countries, however, although the average value of the indicator is higher, the growth rate significantly decreases.

4) Time series of patent applications by residents per million people in RoK and China:

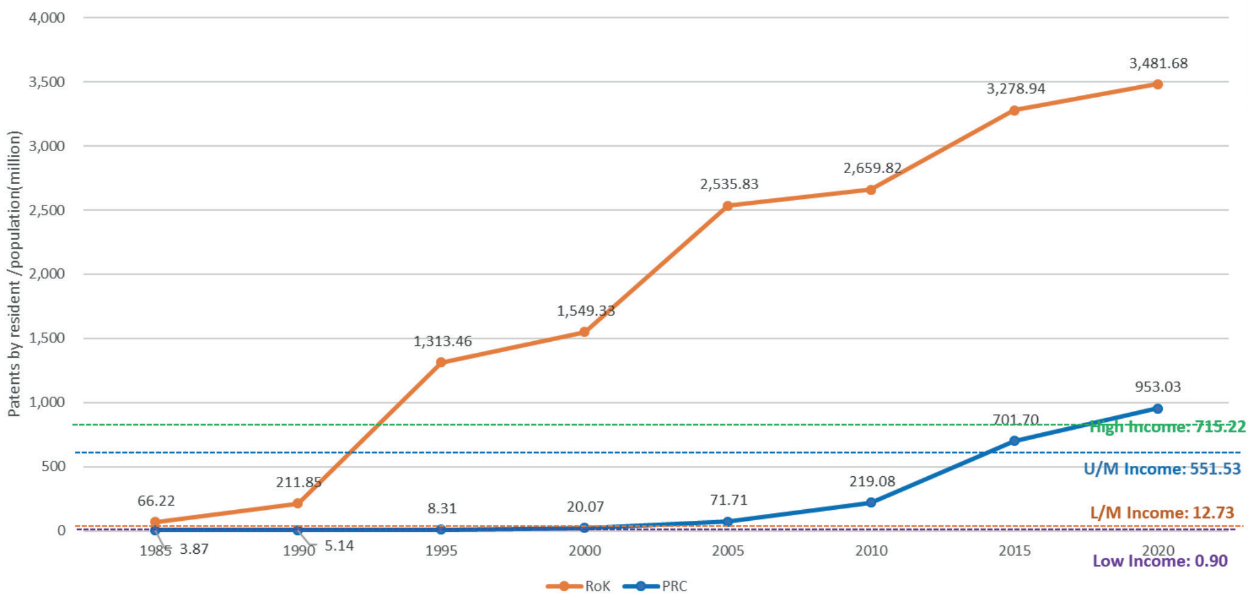
- The plotting graph in Figure 47 shows changes in patent applications by residents per 1 million people by in RoK and China between 1985 and 2020.
- Patent applications by residents in RoK were at the LMI average around 1985. However, they began to take off at an accelerated pace in 1990 and exceeded the HI average around 1995. Afterwards, they have continued to increase and now record a value far beyond the HI average, positioning the RoK as a leading country in terms of invention.
- In China, patent applications by residents were at the level of the LMI average around 1985, then increased at a slow and steady pace from 1995 and have recently exceeded the HI average.
- There is an observed take-off of the indicator in both countries.

Figure 46. LI to HI transition path of patent applications by residents per 1 million people, selected countries



Source: Authors' elaboration.

Figure 47. Change in patent applications by residents per 1 million people, RoK and China, 1985-2020



Source: Authors' elaboration.

Science: Scientific and technical articles per 1 million people.

1) Scientific and technical articles per 1 million people in selected countries in each income group:

- Average scientific and technical articles per 1 million people in LI, LMI, UMI and HI countries is 8.16, 87.09, 323.43 and 1,192.03, respectively, as shown in Figure 48.
- As income increases, the average value of the indicator increases: by 967% from LI to LMI; by 271% from LMI to UMI; and by 268% from UMI to HI.
- Within the LI group, Ethiopia and Uganda record values much beyond the group average. Morocco and Indonesia place above the LMI average, while others in the group are far below the average. Within the UMI group, Romania and China are above the average while others are below the average. Within the HI group, all the selected countries place above the average.

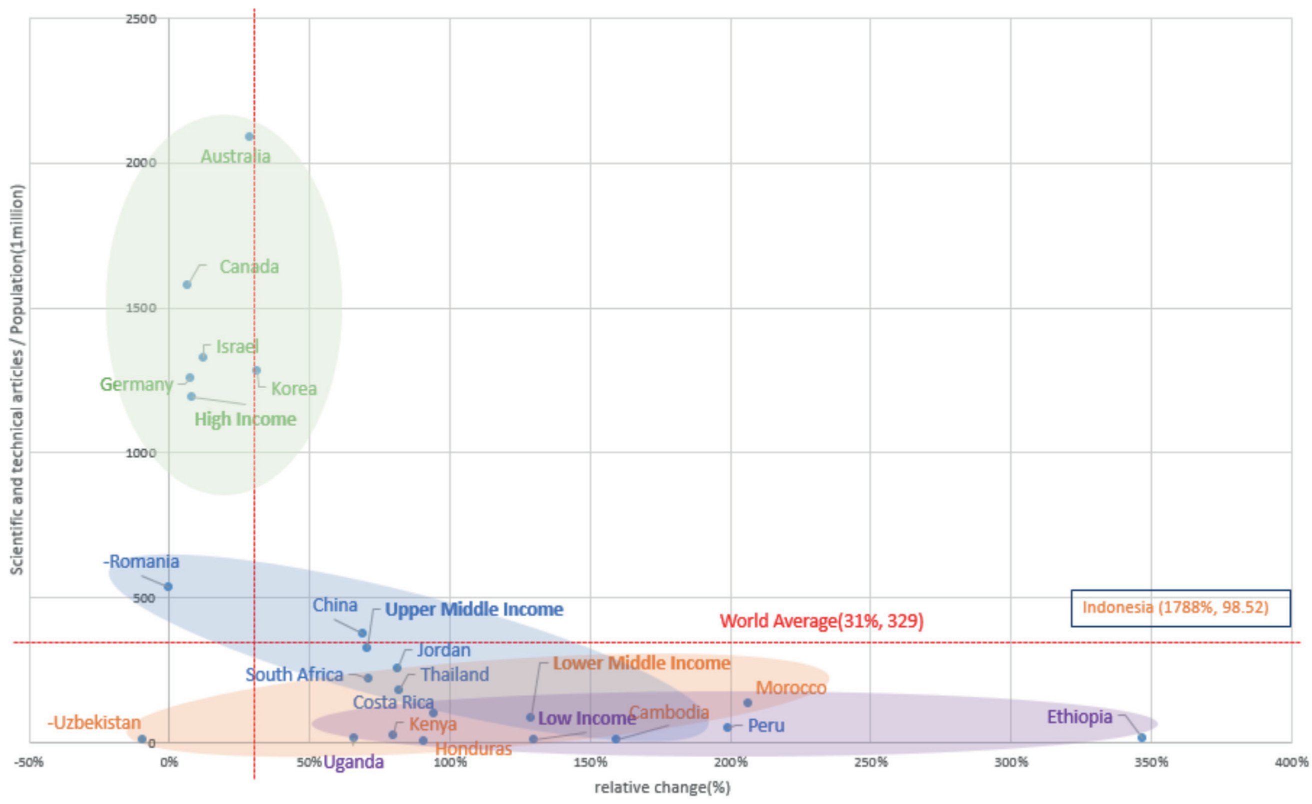
2) Scientific and technical articles per 1 million people and their relative change between 2010 and 2018:

- Figure 49 shows the indicator values and their relative changes over the last eight years for the four income groups and 20 selected countries.
- Global average value and its relative change is 329 and 31%, respectively.
- Values for the LI, LMI and UMI countries are horizontally dispersed across the figure, and are closely placed, while values for the HI countries are vertically dispersed.
- Within the LMI group, Indonesia records a significantly high growth rate while Uzbekistan records a negative growth rate, unlike the other LMI countries.
- Between 2010 and 2018, the relative change in LI, LMI, UMI and HI countries is -129%, 128%, 70% and 8%, respectively.

Figure 48. **Scientific and technical articles per 1 million people in 2018, selected countries**

Source: Authors' elaboration.

Figure 49. **Scientific and technical articles per 1 million people and their relative change, selected countries, 2010-2018**



Source: Authors' elaboration.

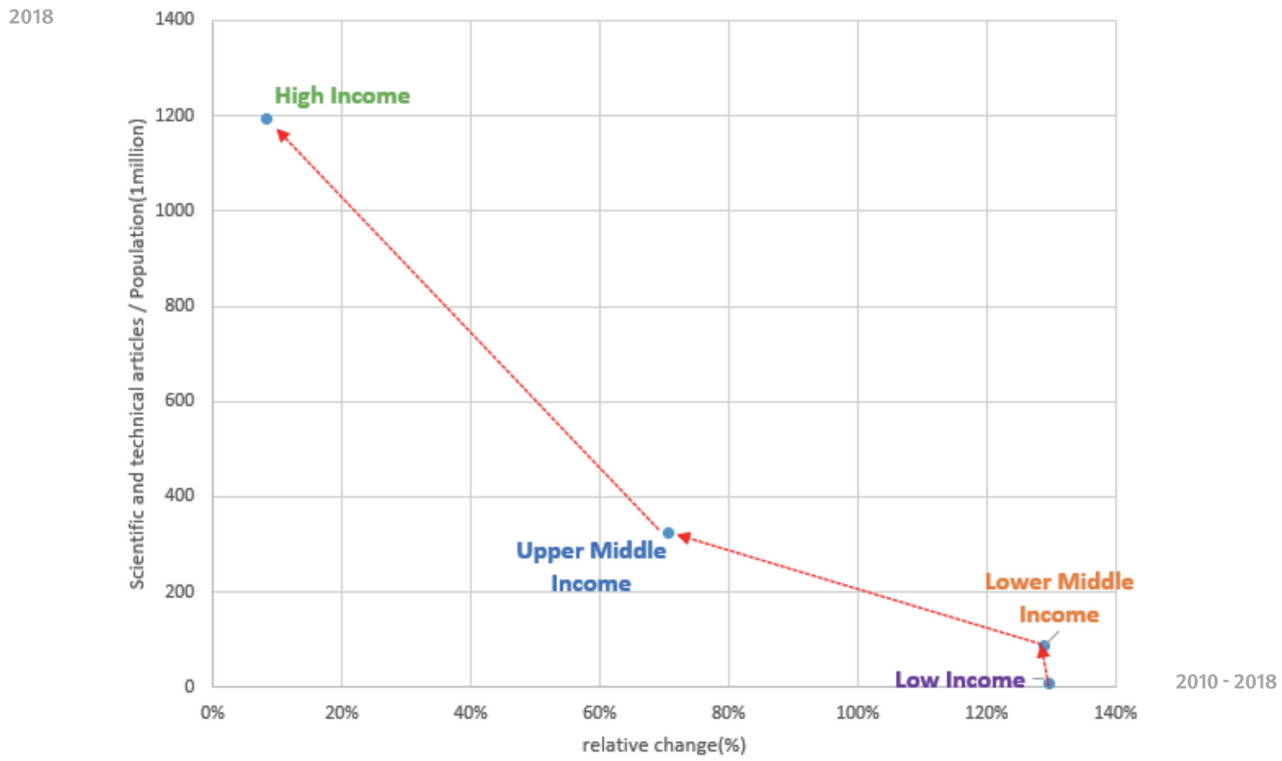
3) Transition path from LI to HI countries:

- As shown in Figure 50, the transition path follows a left, upward direction, a reverse exponential curve.
- Overall, the growth rate decreases as income levels increase.
- There is a significant gap between the values in the HI and UMI groups, suggesting that publication of scientific and technical articles is mainly led by the most advanced countries.

4) Time series of scientific and technical articles per 1 million people in RoK and China:

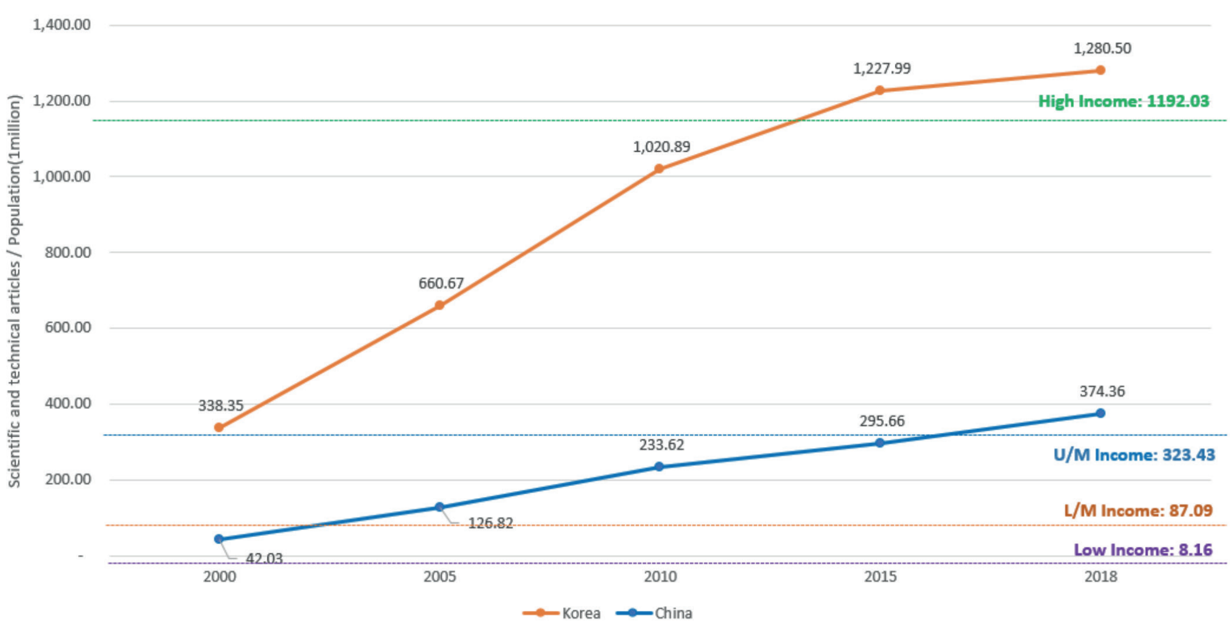
- Figure 51 illustrates the change in number of scientific and technical articles per 1 million people in RoK and China between 2000 and 2018, the period during which both countries experienced successful industrialization.
- While the level of scientific and technical articles in RoK was at the UMI average level around 2000, it then began a fast and steady increase. It reached nearly the HI average around 2015, when the growth rate began to decrease.
- In China's case, while the level of scientific and technical articles was lower than the UMI average level around 2000, it then began to increase at a slow and steady pace. China exceeded the LMI average around 2005, then exceeded the UMI average around 2018.

Figure 50. LI to HI transition path of scientific and technical articles per 1 million people, selected countries



Source: Authors' elaboration.

Figure 51. Change in number of scientific and technical articles, per 1 million people, RoK and China, 2000-2018



Source: Authors' elaboration.

4.2.5 Demand articulation: Public sector

Public sector: Public procurement as % of GDP.

Data availability for this indicator is comparatively low. The *Global Public Procurement Database* (GPPD) lacks information about public procurement for HI countries, while OECD data contains sufficient information for HI countries. Thus, the two data sets (GPPD and OECD) are combined for this analysis.[44] Therefore, only a column chart and a scatter plot with a trendline are displayed for this indicator.

1) Public procurement as % of GDP for selected countries in each income group:

In terms of income group averages, HI countries tend to have larger public procurement than LI and LMI countries. However, UMI countries have a lower share of public procurement than LMI countries.

- Average public procurement in LI, LMI, UMI and HI countries is 7.3%, 13.4%, 8.7% and 14.2%, respectively as shown in Figure 52.
- There is no data available for Ethiopia and Uganda, therefore, the chart only shows the LI group average.
- Germany and Australia have nearly the same high public procurement share (16.5% and 16.4%) among the selected HI countries, exceeding the HI group average.
- The noticeable feature in the LMI group is that public procurement in Kenya and Uzbekistan exceeds the HI group average.

2) Public procurement as % of GDP and GDP per capita:

- Using data for 98 countries, the scatter plotting in Figure 53 indicates that public procurement as a % of GDP and ln GDP per capita, are positively correlated.
- However, there is not much difference in the average values of public procurement as a share of GDP across income groups. At the same time, there is considerable variation within each income group.[45] For example, in the LI group, Mozambique records 0.1% and Afghanistan 19%, while in the UMI group, Paraguay records 0.11% and Kazakhstan 23.7%.
- The equation of the trendline can be expressed as $Y = 0.9644X + 3.0305$

Box 8 provides successful examples in RoK and China of using public procurement to promote new and emerging industries.

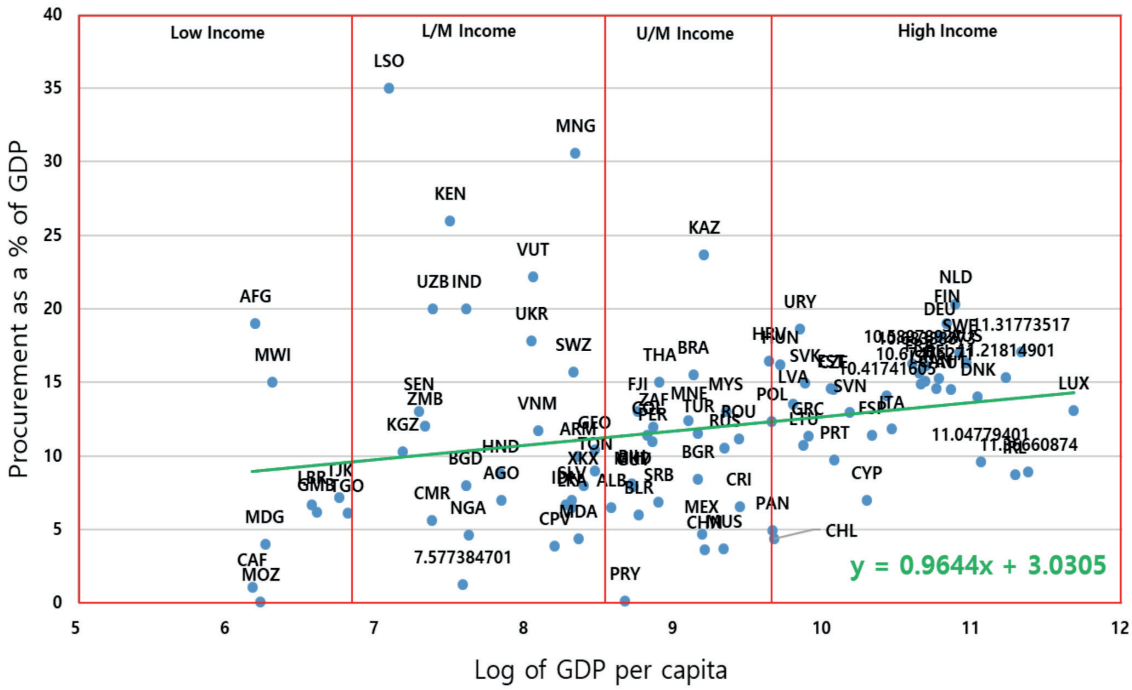
44 It should be noted that the combined data has some limitations as the two data sets use different calculation methodologies for public procurement.

45 The result of this analysis is identical to what Bosio and Djankov (2020) found with 190 country cases.

Figure 52. Public procurement as % of GDP in 2020, selected countries

Source: Authors' elaboration.

Figure 53. Public procurement as % of GDP and per capita GDP, selected countries



Source: Authors' elaboration.

Box 8. Successful public procurement programmes in RoK (computer industry) and China (renewables)

In 1982, the RoK government implemented a public procurement programme for personal computers in public schools to create markets for the newly emerging computer industry, with an initial purchase of 5,000 units, which increased in subsequent years. In 1983, it launched a similar procurement programme for the Government Administration Services' (Kim and Dahlman 1992). The programme enforced local content requirements with technical specifications so that local RoK manufacturers with indigenous technologies could enter and gain a foothold in the new industry.

Tackling its environmental issues and energy security, during the 2000s China promoted its renewable energy industry, mainly solar and wind power, with public procurement programmes. As a latecomer to these sectors, the Chinese government first encouraged foreign companies to enter the Chinese market by creating local renewable markets. With the help of local content requirements and import tariffs on intermediate goods, local Chinese companies successfully accumulated the necessary technological capabilities, and subsequently became a global leader in both the solar and wind power sectors (Gandenberger and Strauch 2018).

Source: Park et al. (2021).

4.2.6 Demand articulation: Private sector

***Private (domestic)*:** ICT imports as a share of total imports.

HI and UMI countries tend to have a larger share of ICT imports than LI and LMI countries. Overall, the validity of this indicator is supported, but the decrease from UMI to HI countries needs to be explained.

1) ICT imports (% of total imports) of selected countries in each income group:

- Figure 54 shows that the average share of ICT imports in LI, LMI, UMI and HI countries is 2.7%, 13.3%, 19.3% and 14.1%, respectively.
- Change in average share of ICT imports from LI to LMI countries increases by 10.6%. and from LMI to UMI by 6%. However, the average share from UMI to HI countries decreases by 5.2%.
- China has the highest share of ICT imports among the 20 selected countries and its share of ICT imports (25.1%) exceeds the UMI group average (19.3%), which is the highest share among the four income groups.

2) ICT imports (% of total imports) and their relative change over the last 10 years:[46]

- Figure 55 shows the shares of ICT imports and their relative change for the four income groups and 20 selected countries.
- Global share of ICT imports and its relative change is 16.8% and 15.1%, respectively.

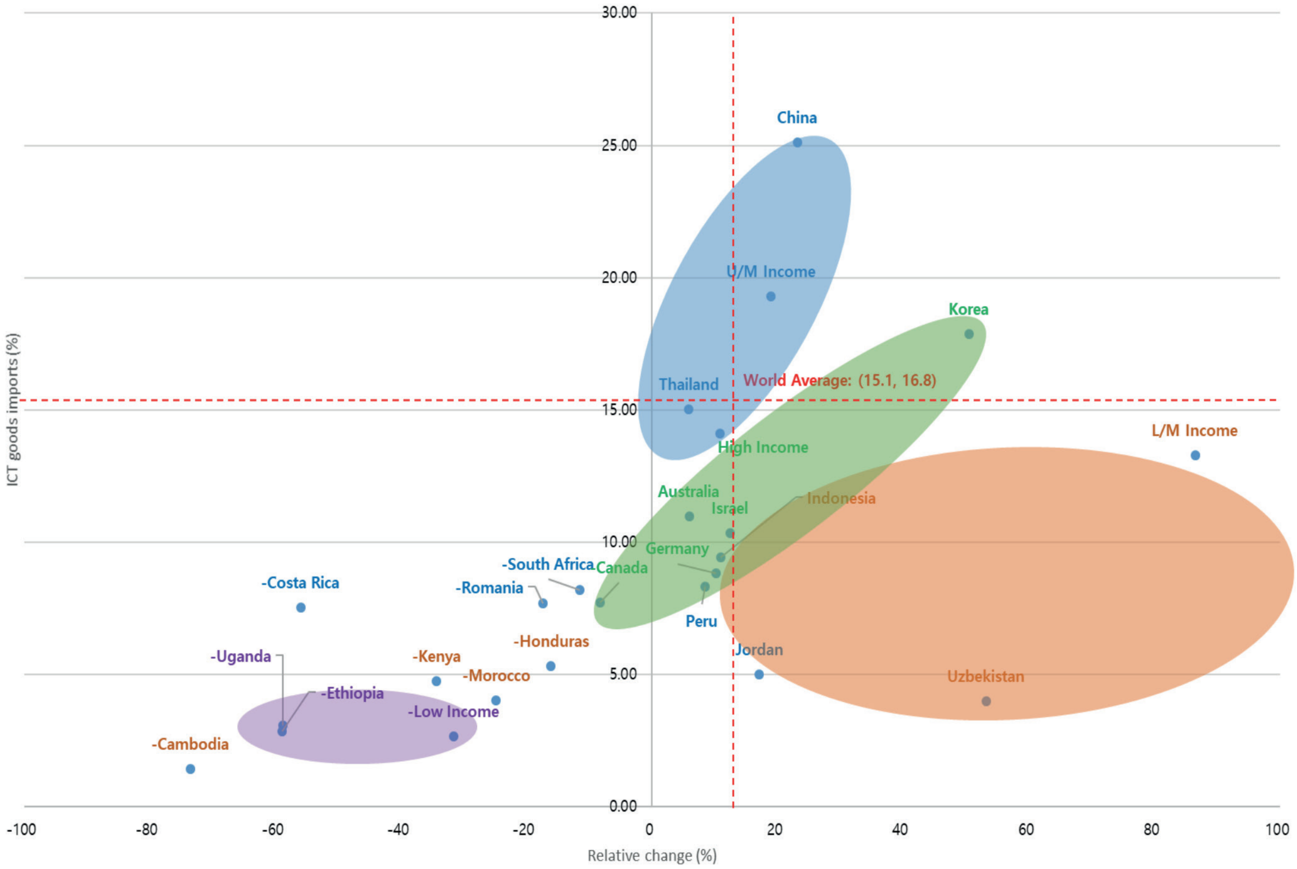
46 Due to data limitations, recent and reference years vary across countries in this analysis.

- LI and HI countries generally do not deviate from their average values, while there is large variation in LMI and UMI countries.
- Costa Rica deviates further left from the UMI average in the figure, indicating that its relative change has significantly decreased over the last 10 years (2009-2019).
- Cambodia deviates further left from the LMI average in the figure, indicating that its relative change has decreased considerably over the last 10 years (2009-2019).
- Over the last 10 years, the relative change in LI (2008-2018) is -32%, the relative change in LMI (2010-2020) is 86%, the relative change in UMI (2010-2020) is 19%, and the relative change in HI (2010-2020) is 11%.

Figure 54. ICT imports as share of total imports in 2020, selected countries

Source: Authors' elaboration.

Figure 55. ICT imports as share of total imports and their relative change, selected countries, 2010-2020



Source: Authors' elaboration.

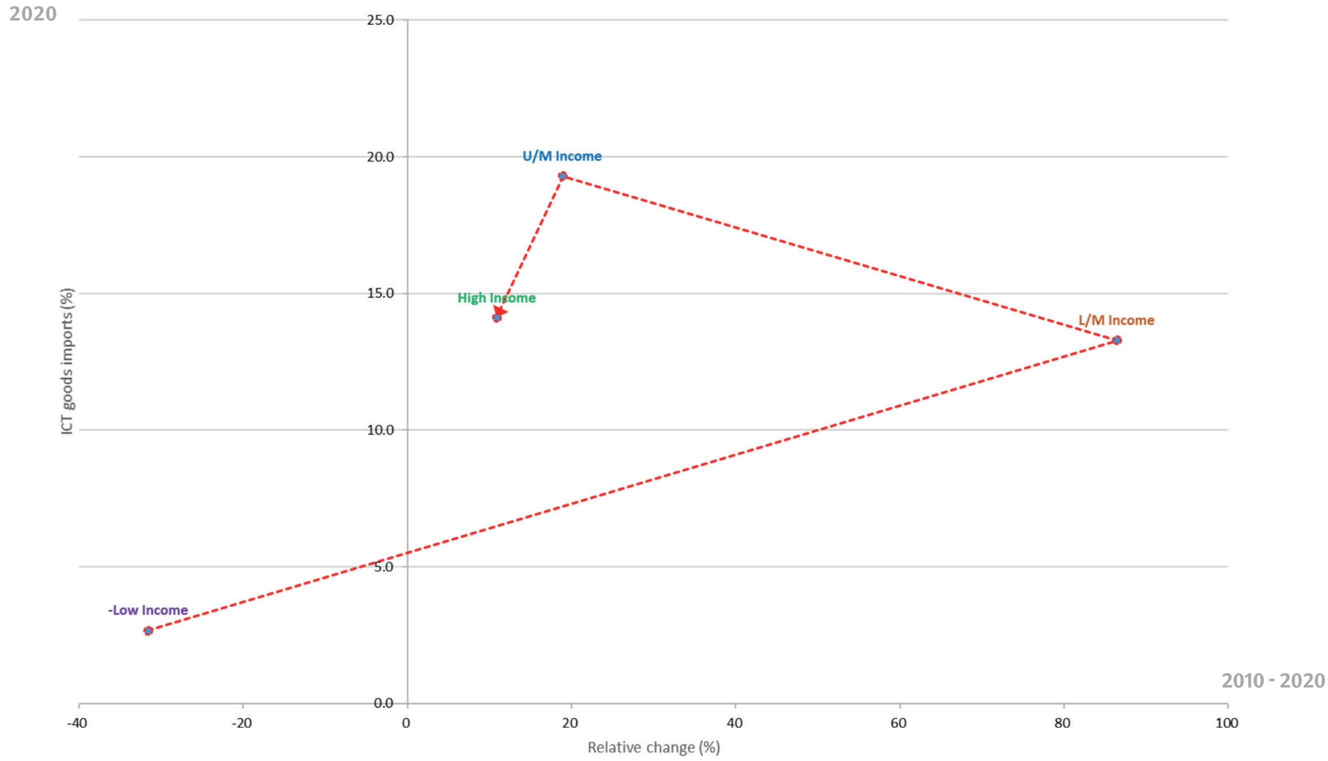
3) Transition path from LI to HI countries:

- As shown in Figure 56, the overall transition path follows a counterclockwise direction.
- The transition path from LI to LMI countries reveals that both share of ICT imports and relative change in that share increase considerably.
- However, the transition path from UMI to HI countries follows a left, downward direction, indicating that HI countries import a smaller share of ICT goods than UMI countries. This may be owing to the technological capabilities of HI countries.

4) Time series of ICT imports (% of total imports) in RoK and China:

- Figure 57 presents data from RoK and China (2000-2020), which have experienced successful industrialization since the late 20th century.
- In RoK, share of ICT imports decreased from around the UMI group average in 2000 to the HI group average in 2010, but has increased since then.
- The share of ICT imports in China remains above the UMI average and has increased from 2010 onwards.
- Both countries' participation in the global value chain should be carefully considered in order to explain the historical patterns.

Figure 56. LI to HI transition path of ICT imports as a share of total imports, selected countries



Source: Authors' elaboration.

Figure 57. Change in ICT imports as a share of total imports, RoK and China, 2000-2020

Source: Authors' elaboration.

Figure 58. Medium- and high-tech exports (% of total manufactured exports) in 2019, selected countries

Source: Authors' elaboration.

***Private (foreign)*:** Medium- and high-tech exports as a share of total manufacturing exports.

1) Medium- and high-tech exports (% manufactured exports) of selected countries in each income group:

Higher-income countries tend to have a larger share of medium and high-tech exports than lower-income countries. This confirms the assumption and supports the validity of this indicator.

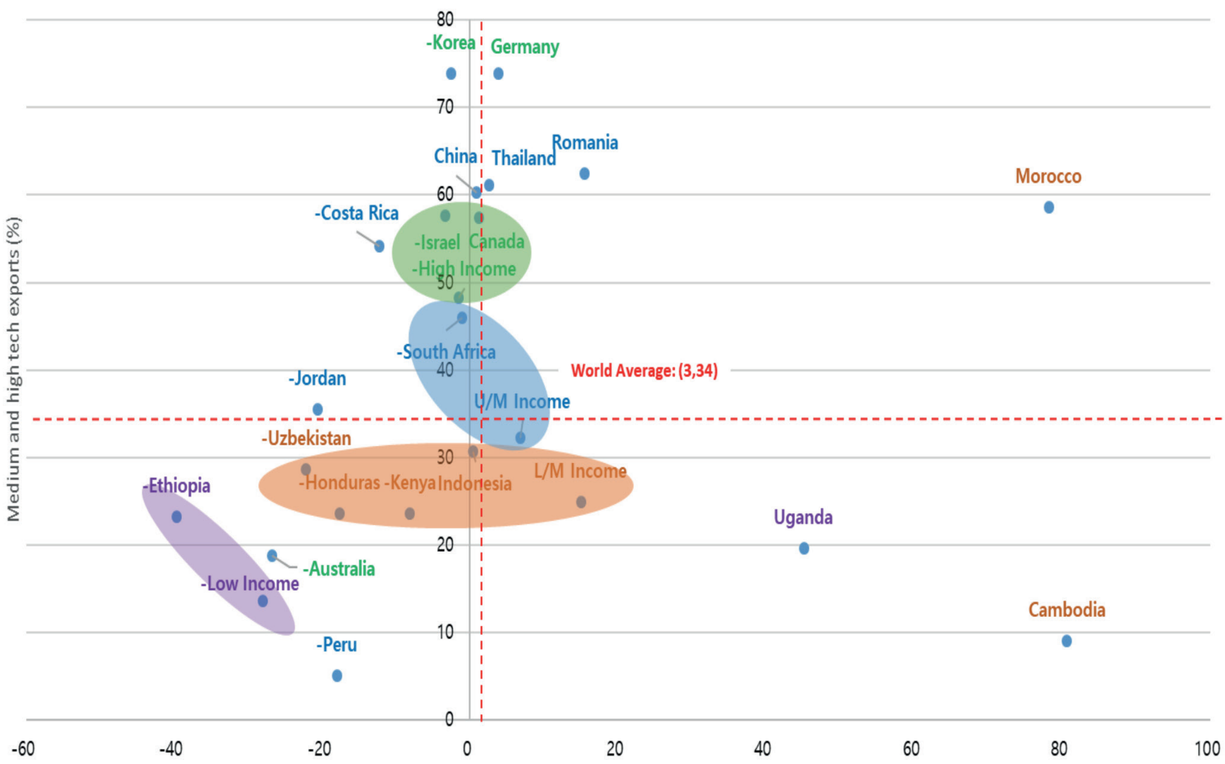
- Average share of medium- and high-tech exports in LI, LMI, UMI and HI countries is 14%, 25%, 32% and 48%, respectively, as shown in Figure 58.
- Average share of medium- and high-tech exports from LI to LMI countries increases by 11%, from LMI to UMI countries by 7%, and from UMI to HI countries by 12%.
- RoK and Germany have the highest share of medium- and high-tech exports among the 20 selected countries, each with 74%.
- Shares in China, Thailand, Costa Rica and Romania, among UMI countries, and Morocco, among LMI countries, surpass the HI average of 48%.

2) Shares of medium- and high-tech exports (% manufactured exports) and their relative change over the last 10 years (2009-2019):

- Figure 59 shows the share of medium- and high-tech exports and their relative changes for the four income groups and 20 selected countries.
- Global share of medium- and high-tech exports and its relative change is 34% and 3%, respectively.
- Despite a few outliers, generally, LI and HI countries do not deviate from the group average, while there is a large variation among LMI and UMI countries.
- Values for Romania and Peru deviate further up and down the graph, respectively, from the UMI group average, indicating that their shares of medium- and high-tech exports have significantly varied over the last 10 years.

- Values for Morocco and Cambodia deviate further right from the LMI average on the graph, indicating that their relative changes have increased considerably over the last 10 years.
- Over the last 10 years, the relative change in LI is -27%; in LMI, 15%; UMI, 7%; and in HI, 2%.

Figure 59. **Medium- and high-tech exports (% of total manufactured imports) and their relative change, 2009-2019, selected countries**



Source: Authors' elaboration.

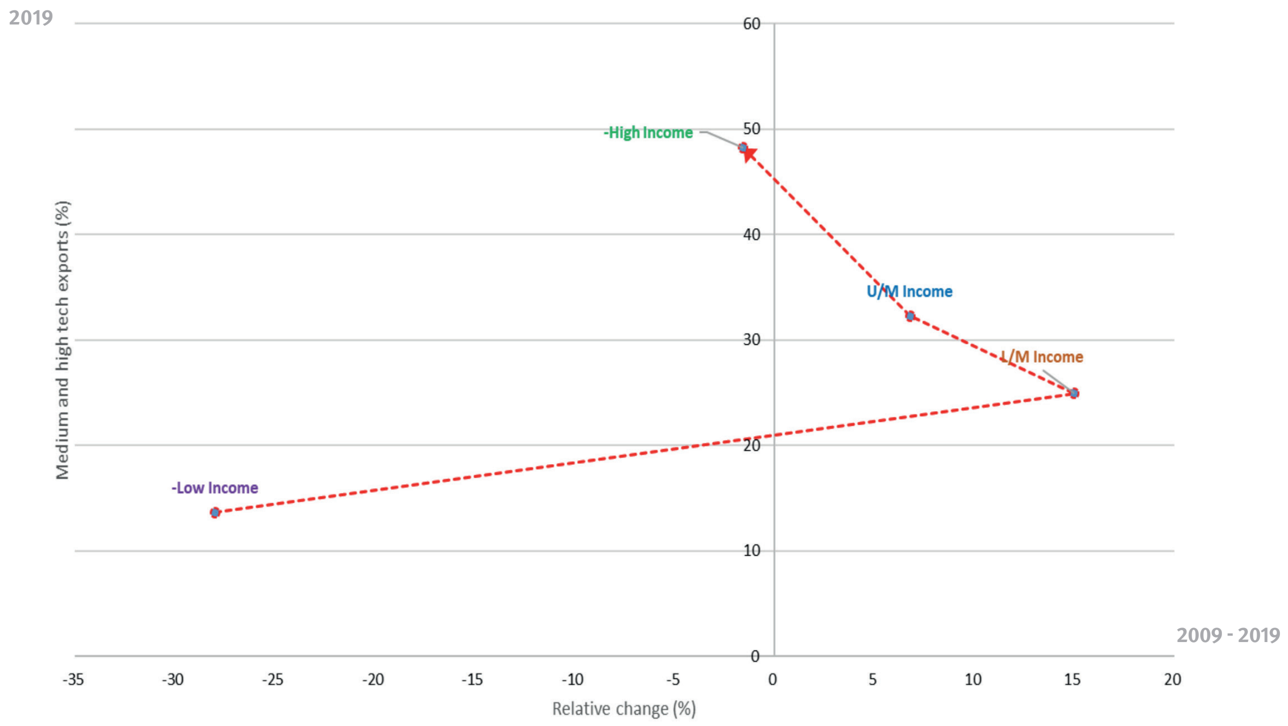
3) Transition path from LI to HI countries:

- As shown in Figure 60, the overall transition path follows a counterclockwise direction.
- Relative change from LI to LMI countries has increased considerably over the last 10 years.
- The transition path from UMI to HI countries follows left, upward direction, indicating that, while HI countries have a larger share of medium- and high-tech exports its relative change has dropped compared to UMI countries, and is currently stagnating.
- This suggests that a logarithmic or S-curve transition path.

4) Time series of medium- and high-tech exports (% total manufactured exports) in RoK and China:

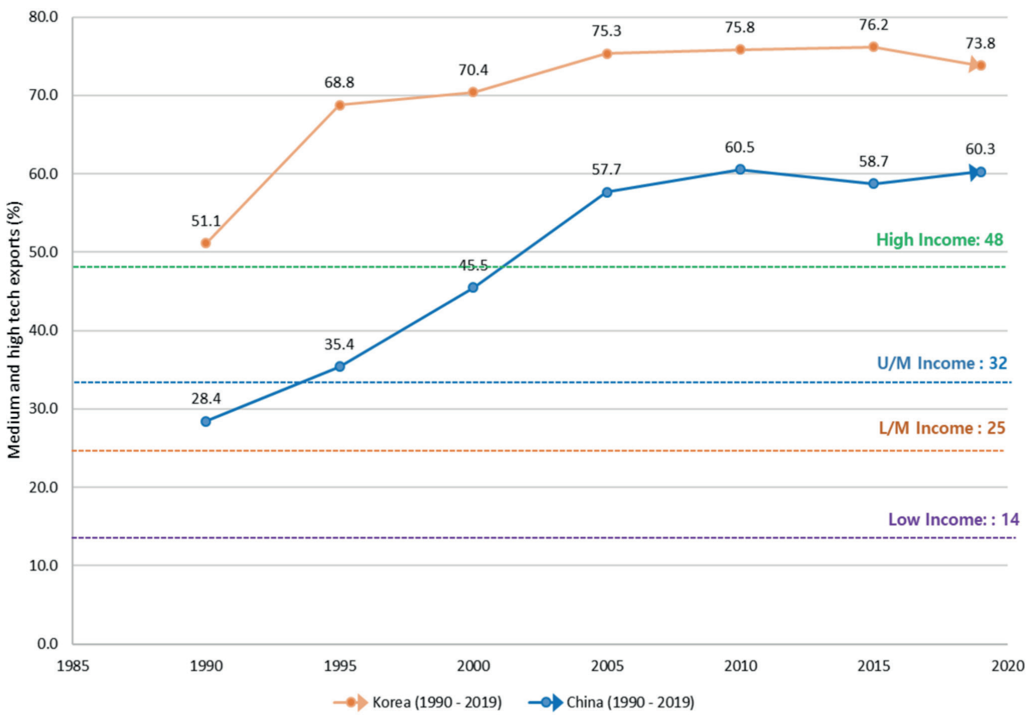
- Figure 61 uses RoK and China data (1990-2019) presented in Figure 59.
- In RoK, the share increased rapidly from 1990 to 2005, but has stagnated since. Still, since 1990, RoK's share has been higher than the HI group average.
- In China, the share also increased rapidly from 1990 to 2005, and has stagnated since.

Figure 60. LI to HI transition path of medium- and high-tech exports (% of total manufactured imports)



Source: Authors' elaboration.

Figure 61. Change in medium- and high-tech exports (as % of total manufactured imports), RoK and China, 1990-2019



Source: Authors' elaboration.

5 Embedding the tool and its indicators in the policy process, with examples

Fostering industrial innovation through dedicated policy interventions requires an understanding of a complex array of factors that drive innovation, and of the capabilities and behaviour of the actors who perpetrate activities in response to the policy. Effective innovation policies involve whole-of-government approaches, entailing a systematic appraisal of the nature and scale of development challenges and how these can be tackled trough industrial innovation activities, the characteristics of innovative firms and the internal and systemic factors that can influence innovation (OECD and Eurostat 2018). In addition, policies to foster industrial innovation are more effective when they have incorporated—into either policy goals or processes—specific contexts, history and strategic challenges that each country faces than when they are ignorant of country specificity.

In this section, we present the concept of a heatmap dashboard, which aims to 1) sketch the overall landscape of selected countries using the tool's indicators, and 2) facilitate the comparative positioning and the identification of gaps of each country using examples.

5.1 Concept of a heatmap dashboard

Based on calculations of all the indicators for each country in the analysis, we have developed a heatmap dashboard that compares the overall performance of each country with the performance of the other exemplary countries discussed in Chapter 4 or the income group average. The dashboard features three images/icons to present the performance of a country for a specific indicator: traffic lights (red, yellow, green), plus (+) and minus (-), and alphabets grades (A, B, C, D):

1) Traffic light (comparative signal) make intra-income group competitiveness more prominent.

A red light indicates that a country is performing below 85% of the average value of its income group for a specific indicator; yellow indicates that a country is performing close (85~115%) to the average value of its income group for a specific indicator; green indicates that a country is performing above 115% of the average value of its income group for a specific indicator.

2) Minus (-) and plus (+) signs show the rate (speed) of improvement during a recent period (when applicable).

A minus (-) sign indicates that a country has improved below the average of its income group over a certain period for a specific indicator; a plus (+) sign indicates that a country has improved above the average of its income group over a certain period for a specific indicator.

3) Alphabet grades represent an absolute performance of each country compared to the average value of each income group.

"D" indicates that a country is performing below the average performance of LI countries for a specific indicator; "C" indicates that a country is performing equal to or above the average of LI countries, but below the average performance of LMI countries for a specific indicator; "B" indicates that a country is performing equal to or above the average of LMI countries, but below the average of UMI countries; and "A" indicates that a country is performing equal to or above the average of UMI countries, but below the average of HI countries. Finally, "S" indicates that a country is performing equal to or above the average of HI countries.

The combination of these three images/icons helps the heatmap dashboard visualize the following factors simultaneously:

- Overall performance of a country across all the indicators analysed within the indicator system.
- Performance of a country compared to the average values of all income groups in each indicator.
- Indicators in which a country is under- or over-performing and improving slower or faster against the average performance of its close comparators within the same income group (intra-income group comparison).

5.2 Heatmap dashboard of exemplary diagnosis

Based on the indicator system, we constructed a table comprising all indicator values from the exemplary diagnosis of selected countries along with the average value of the indicator and the growth rate by different income groups as shown in Figure 62. We then created a heatmap dashboard Figure 63 for 15 of the 20 countries that had been selected for the exemplary diagnosis, in line with the concept as explained earlier in this document.

We selected one country from three of the four income groups and provide brief interpretations using data from the heatmap dashboard: Ethiopia from the LI group, Honduras from the LMI group, and China from the UMI group.

To give readers a better picture of a country's overall performance when it comes to gaps, country gap profiles—with radar charts—for Ethiopia, Honduras and China are presented in in Figures 64, 65 and 66, respectively. In the radar charts, average values for the LI, LMI, UMI and HI groups for each indicator are converted into 25%, 50%, 75% and 100%, respectively. The value of each indicator of a country is positioned accordingly. Readers can identify a country's relative position for each indicator and interpret gaps within their country context.

Ethiopia is, in general, behind compared to its comparator countries in the LI group. The dashboard shows eight red lights, with only three green lights across the country's portfolio. It performs below the LI group average in terms of infrastructure, institution, interaction (network) and capabilities. However, the country seems to have put efforts towards improvement of these indicators with most of the signs indicating +. The only indicators that Ethiopia is performing better than its LI comparators are network and capability in science. In terms of demand articulation, its overall performance is not bad, with yellow and green lights for the three indicators.

Honduras has both positive (three green lights) and negative (six red lights) aspects in its performance, according to the dashboard. Positive aspects are to do with knowledge infrastructure and IRP related indicators. In contrast, it is behind its LMI comparator countries in terms of institutions (except IPR) and capabilities. In particular, Honduras shows very weak performance on business friendliness and scientific and technological innovation activities—in fact, below the LI average.

China shows an overall strong performance in most of the categories in its portfolio, with 11 green lights, 4 yellow lights, and no red lights. According to the dashboard, the country needs to improve in the area of interactions in technology and science. However, China may compensate for this gap with domestic technological capabilities. According to NISTEP (2022), China has already surpassed the United States in terms of both quantity and quality[47] of scientific papers. However, this should be interpreted in a more in-depth way within its national policy context.

47 As measured by the number of top 1% and 10% most-cited papers by NISTEP (2022).

Figure 62. Analysis of the indicator system, selected countries

									Africa				Asia				Latin America			North Africa & Middle East		East Europe	Central Asia
Tool title	**Component**	**Category**	**Sub-category**	**Indicator**	**HIC's average**	**UMIC's average**	**LMIC's average**	**LIC's average**	**Ethiopia**	**Kenya**	**South Africa**	**Uganda**	**Cambodia**	**Indonesia**	**PRC**	**Thailand**	**Costa Rica**	**Honduras**	**Peru**	**Jordan**	**Morocco**	**Romania**	**Uzbekistan**
System failure framework	Reflexivity failure	Infrastructure	Physical	Electricity production capacity (kW) per capita	8728 (-7%)	4623 (37%)	1041 (26%)	170 (-23%)	123 (76%)	205 (16%)	3826 (-19%)	102 (25%)	470 (591%)	1005 (34%)	5858 (72%)	2521 (16%)	2456 (17%)	1104 (35%)	1656 (28%)	1919 (7%)	1003 (39%)	3040 (0%)	1809 (5%)
			Digital	Fixed broadband subscriptions per 100 people	35.79 (37%)	26.13 (213%)	3.68 (273%)	0.47 (713%)	0.18 (3835%)	1.25 (7575%)	2.20 (51%)	0.13 (197%)	1.40 (461%)	4.29 (355%)	33.60 (264%)	16.44 (240%)	19.49 (125%)	4.01 (265%)	9.23 (187%)	6.18 (53%)	5.70 (265%)	29.55 (102%)	14.40 (3380%)
			Knowledge	Enrollment ratio in tertiary education	79 (9.9%)	58 (78.0%)	27 (45.0%)	9 (15.1%)	10 (176%)	10 (151%)	24 (30.7%)	5 (40%)	15 (28%)	36 (74%)	58 (140%)	49 (9%)	58 (27%)	26 (48%)	71 (108%)	34 (-27%)	41 (182%)	51 (-26%)	16 (71%)
		Institution	R&D investment	Expenditure on R&D, % of GDP	2.37 (25%)	1.23 (62%)	0.52 (3%)	n/a	0.24 (13%)	0.36 (94%)	0.66 (-7%)	0.36 (-60%)	0.05 (137%)	0.08 (237%)	1.71 (40%)	0.23 (387%)	0.48 (-22%)	0.04 (-3%)	0.08 (107%)	0.42 (64%)	0.60 (17%)	0.45 (3%)	0.15 (-9%)
			IPR protection	Patents by foreigners per million people	560.88 (28%)	89.56 (29%)	18.77 (19%)	1.95 (30%)	0.46 (59%)	0.65 (-71%)	103.63 (10%)	0.13 (50%)	14.83 (853%)	25.05 (34%)	107.97 (55%)	95.44 (821%)	102.86 (-14%)	32.61 (-7%)	34.64 (338%)	29.50 (-30%)	66.05 (176%)	2.44 (31%)	6.78 (-11%)
			Business	New business registration per 1000 people (age 15-64)	4,60	6,30	0,44	n/a	n/a	1,55	12,50	n/a	0,54	n/a	8,58	1,29	3,61	n/a	3,80	0,43	2,24	6,23	2,71
			Finance	Market capitalization of listed domestic companies, % of GDP	1.34 (70%)	0.73 (80%)	0.69 (82%)	n/a	n/a	0.21 (48%)	3.13 (14%)	n/a	n/a	0.47 (38%)	0.83 (203%)	1.08 (96%)	0.03 (32%)	n/a	0.43 (-16%)	0.42 (-41%)	0.57 (-5%)	0.10 (80%)	n/a
		Interaction (or Network)	Production	Share of firms exporting directly/ indirectly (at least 10% of sales)	24	15	13	11	9	16	10	13	14	10	21	5	12	11	15	27	31	15	6
			Technology	Intellectual property payments per million GDP	7000 (38.4%)	2850 (29.6%)	1540 (30.2%)	83 (-57.9%)	22 (-35%)	757 (93%)	3570 (-23%)	0 (-100%)	808 (45%)	1445 (-32%)	2578 (20%)	9013 (-0.2%)	10035 (138%)	2618 (37%)	1727 (29%)	560 (536%)	1320 (305%)	3554 (33%)	1881 (175%)
			Science	International co-authored scientific articles per 100000 people	113.9 (21.2%)	15.6 (134.4%)	5.8 (133.3%)	2.1 (53.0%)	3 (402%)	7 (127%)	30 (164%)	1 (-76%)	3 (152%)	3 (422%)	13 (211%)	5 (-65%)	24 (143%)	2 (251%)	11 (286%)	44 (237%)	12 (200%)	38 (110%)	0 (-77%)
		Capability	Production (capacity)	Gross fixed capital formation as % of GDP	22.29 (8.28%)	34.34 (11.4%)	25.31 (-7.9%)	25.27 (0.5%)	30.58 (-4.8%)	19.35 (-7.2%)	13.72 (-21.9%)	23.52 (-8.6%)	24.02 (48.4%)	31.72 (2.3%)	42.49 (-3.3%)	23.24 (-3.1%)	16.58 (-14.8%)	18.98(-12.0%)	19.87(-15.5%)	14.34 (-50.4%)	26.45 (-13.7%)	23.84 (-8.6%)	36.79 (62.9%)
			Production (quality)	ISO 9001 certificates per 10 million people	3402	1727	183	10	4	85	573	27	47	251	2301	1324	677	163	495	564	298	5159	64
			Technology	Patents by resident per million people	715.22 (1%)	551.53 (308%)	12.73 (65%)	0.90 (-93%)	0.05 (50%)	6.34 (343%)	9.14 (-34%)	0.28 (30%)	0.06 (0%)	4.79 (157%)	953.14 (359%)	12.36 (-29%)	2.36 (50%)	0.81 (300%)	3.79 (221%)	3.53 (-20%)	6.77 (64%)	42.42 (-41%)	10.40 (-3%)
			Science	Scientific and technical articles per million people	1192.03 (8%)	323.43 (71%)	87.09 (129%)	8.16 (130%)	17.35 (347%)	23.19 (80%)	219.34 (71%)	14.71 (66%)	8.72 (160%)	98.52 (1788%)	374.40 (69%)	179.28 (82%)	99.60 (94%)	4.55 (91%)	49.43 (199%)	257.50 (81%)	137.00 (207%)	537.19 (-0.24%)	10.34 (-10%)
	Demand articulation failure	Domestic market	Public sector	Public procurement as % of GDP	14,2	8,7	13,4	7,3	n/a	26	12	n/a	n/a	7	4	15	7	9	11	n/a	n/a	10	20
			Private sector (domestic)	Share of ICT imports in total imports	14.1 (10.9%)	19.3 (19.0%)	13.3 (86.5%)	2.7 (-31.6%)	2 (-59%)	4 (-34%)	8 (-12%)	3 (-59%)	1 (-74%)	9 (11%)	25 (23%)	15 (6%)	7 (-56%)	5 (-16%)	8 (8%)	4 (17%)	4 (-25%)	7 (-17%)	3 (53%)
		Int'l market	Private sector (foreign)	Share of medium/high-tech exports in total manufactured exports	48 (-1.6%)	32 (6.8%)	25 (15.0%)	14 (-28.0%)	23 (-49%)	23 (-8%)	45 (-1.1%)	19 (45%)	9 (81%)	30 (0.4%)	60 (0.8%)	61 (3%)	54 (-12%)	24 (-18%)	5 (-18%)	35 (-21%)	58 (78%)	62 (16%)	28 (-22%)

Source: Authors' elaboration.

Figure 63. Heatmap dashboard, selected countries

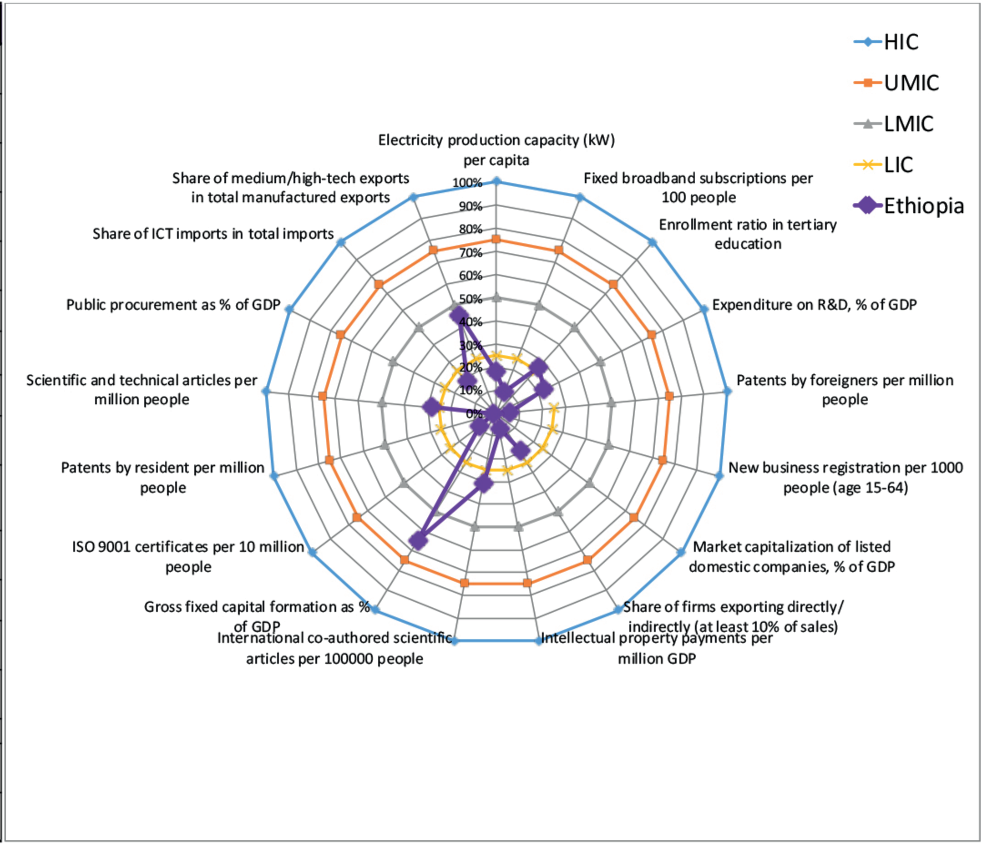
									Africa				Asia				Latin America			North Africa & Middle East		East Europe	Central Asia
Tool title	Component	Category	Sub-category	Indicator	HIC's average	UMIC's average	LMIC's average	LIC's average	Ethiopia	Kenya	South Africa	Uganda	Cambodia	Indonesia	PRC	Thailand	Costa Rica	Honduras	Peru	Jordan	Morocco	Romania	Uzbekistan
System failure framework	Reflexivity	Infrastructure	Physical	Electricity production capacity (kW) per capita	8728 (-7%)	4623 (37%)	1041 (26%)	170 (-23%)	D+	C-	B-	D+	C+	C+	A+	B-	B-	B+	B-	B-	C+	B-	B-
			Digital	Fixed broadband subscriptions per 100 people	35.79 (37%)	26.13 (213%)	3.68 (273%)	0.47 (713%)	D+	C+	C-	D-	C+	B+	A+	B+	B-	B-	B-	B-	B-	A-	B+
			Knowledge	Enrollment ratio in tertiary education	79 (9.9%)	58 (78.0%)	27 (45.0%)	9 (15.1%)	C+	C+	C-	D+	C-	B+	A+	B-	A-	C+	A+	B-	B+	B-	C+
		Institution	R&D investment	Expenditure on R&D, % of GDP	2.37 (25%)	1.23 (62%)	0.52 (3%)	n/a	C	C+	B-	C	C+	C+	A-	C+	C-	C-	C+	C+	C-	C-	C-
			IPR protection	Patents by foreigners per million people	560.88 (28%)	89.56 (29%)	18.77 (19%)	1.95 (30%)	D+	D+	A-	D+	C+	B+	A+	A+	A-	B-	B+	B-	B+	C+	C-
			Business	New business registration per 1000 people (age 15-64)	4,60	6,30	0,44	n/a	n/a			n/a		n/a				n/a					
			Finance	Market capitalization of listed domestic companies, % of GDP	1.34 (70%)	0.73 (80%)	0.69 (82%)	n/a	n/a	C-	S-	n/a	n/a	C-	A+	A+	C-	n/a	C-	C-	C-	C	n/a
		Interaction (or Network)	Production	Share of firms exporting directly/ indirectly (at least 10% of sales)	24	15	13	11	D	A	D	B	B	D	A	D	C	C	A	S	S	A	D
			Technology	Intellectual property payments per million GDP	7000 (38.4%)	2850 (29.6%)	1540 (30.2%)	83 (-57.9%)	D+	C+	A-	D-	C+	C+	B-	S-	S+	B+	B-	C+	C+	A+	B+
			Science	International co-authored scientific articles per 100000 people	113.9 (21.2%)	15.6 (134.4%)	5.8 (133.3%)	2.1 (53.0%)	C+	B-	A-	D-	C+	C+	B+	C-	A+	D+	B+	A+	B+	A-	D-
		Capability	Production (capacity)	Gross fixed capital formation as % of GDP	22.29 (8.28%)	34.34 (11.4%)	25.31 (-7.9%)	25.27 (0.5%)															
			Production (quality)	ISO 9001 certificates per 10 million people	3402	1727	183	10	D	C	B	C	C	B	A	B	B	C	B	B	B	S	C
			Technology	Patents by resident per million people	715.22 (1%)	551.53 (308%)	12.73 (65%)	0.90 (-93%)	D-	C+	C-	D-	D-	C+	S+	C-	C-	D+	C+	C-	C-	B-	C-
			Science	Scientific and technical articles per million people	1192.03 (8%)	323.43 (71%)	87.09 (129%)	8.16 (130%)	C+	C-	B+	C-	C+	B+	A-	B+	B+	D-	C+	B+	B+	A-	C-
	Demand articulation	Domestic market	Public sector	Public procurement as % of GDP	14,2	8,7	13,4	7,3	n/a			n/a	n/a							n/a	n/a		
			Private sector (domestic)	Share of ICT imports in total imports	14.1 (10.9%)	19.3 (19.0%)	13.3 (86.5%)	2.7 (-31.6%)	D-	C-	C-	C-	D-	C-	S+	B-	C-	C-	C-	C-	C-	C-	C-
		Int'l market	Private sector (foreign)	Share of medium/high-tech exports in total manufactured exports	48 (-1.6%)	32 (6.8%)	25 (15.0%)	14 (-28.0%)	C-	C-	A-	C+	D+	B-	S-	S-	S-	C-	D-	A-	S+	S+	

Note: Purple = LI; orange = LMI; blue = UMI. Cells without (-), (+), or traffic signals indicate low data availability. N/A: data not available. Grades are not given for indicators having low correlation with income level.

Source: Authors' elaboration

Figure 64. Country gap profile: Ethiopia

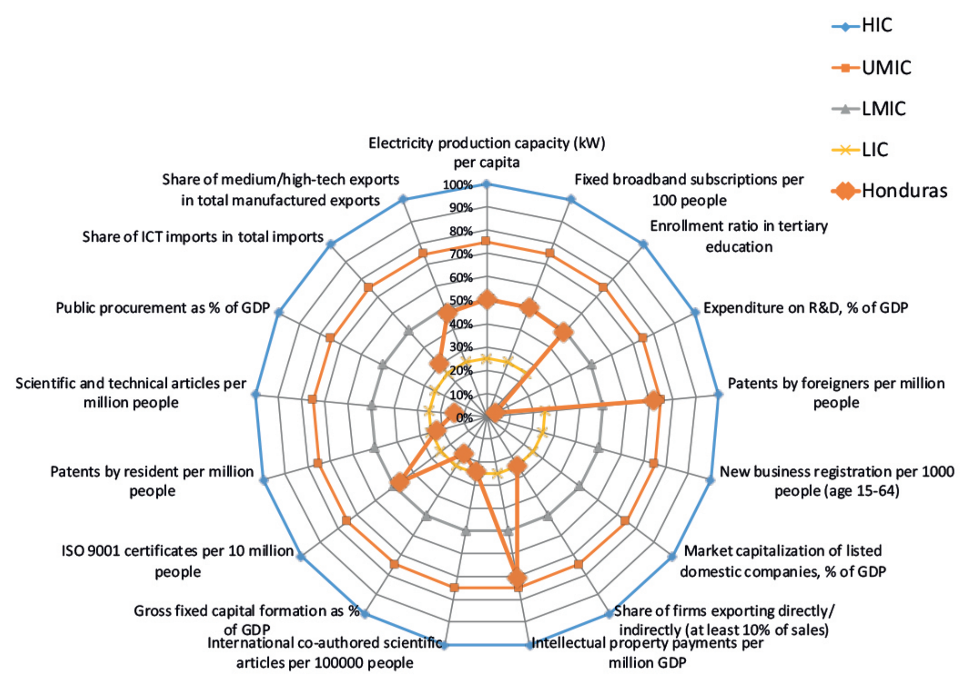
Tool title	Component	Category	Sub-category	Indicator	HIC's average	UMIC's average	LMIC's average	LIC's average	Ethiopia
System failure framework	Reflexivity failure	Infrastructure	Physical	Electricity production capacity (kW) per capita	8728 (-7%)	4623 (37%)	1041 (26%)	170 (-23%)	123 (76%)
			Digital	Fixed broadband subscriptions per 100 people	35.79 (37%)	26.13 (213%)	3.68 (273%)	0.47 (713%)	0.18(38 35%)
			Knowledge	Enrollment ratio in tertiary education	79 (9.9%)	58 (78.0%)	27 (45.0%)	9 (15.1%)	10 (176%)
		Institution	R&D investment	Expenditure on R&D, % of GDP	2.37 (25%)	1.23 (62%)	0.52 (3%)	n/a	0.24 (13%)
			IPR protection	Patents by foreigners per million people	560.88 (28%)	89.56 (29%)	18.77 (19%)	1.95 (30%)	0.46 (59%)
			Business	New business registration per 1000 people (age 15-64)	4,60	6,30	0,44	n/a	n/a
			Finance	Market capitalization of listed domestic companies, % of GDP	1.34 (70%)	0.73 (80%)	0.69 (82%)	n/a	n/a
		Interaction (or Network)	Production	Share of firms exporting directly/ indirectly (at least 10% of sales)	24	15	13	11	9
			Technology	Intellectual property payments per million GDP	7000 (38.4%)	2850 (29.6%)	1540 (30.2%)	83 (-57.9%)	22 (-35%)
			Science	International co-authored scientific articles per 100000 people	113.9 (21.2%)	15.6 (134.4%)	5.8 (133.3%)	2.1 (53.0%)	3 (402%)
		Capability	Production (capacity)	Gross fixed capital formation as % of GDP	22.29 (8.28%)	34.34 (11.4%)	25.31 (-7.9%)	25.27 (0.5%)	30.58 (-4.8%)
			Production (quality)	ISO 9001 certificates per 10 million people	3402	1727	183	10	4
			Technology	Patents by resident per million people	715.22 (1%)	551.53 (308%)	12.73 (65%)	0.90 (-93%)	0.05 (50%)
			Science	Scientific and technical articles per million people	1192.03 (8%)	323.43 (71%)	87.09 (129%)	8.16 (130%)	17.35 (347%)
	Demand articulation failure	Domestic market	Public sector	Public procurement as % of GDP	14,2	8,7	13,4	7,3	n/a
			Private sector (domestic)	Share of ICT imports in total imports	14.1 (10.9%)	19.3 (19.0%)	13.3 (86.5%)	2.7 (-31.6%)	2 (-59%)
		Int'l market	Private sector (foreign)	Share of medium/high-tech exports in total manufactured exports	48 (-1.6%)	32 (6.8%)	25 (15.0%)	14 (-28.0%)	23 (-49%)



Source: Authors' elaboration.

Figure 65. Country gap profile: Honduras

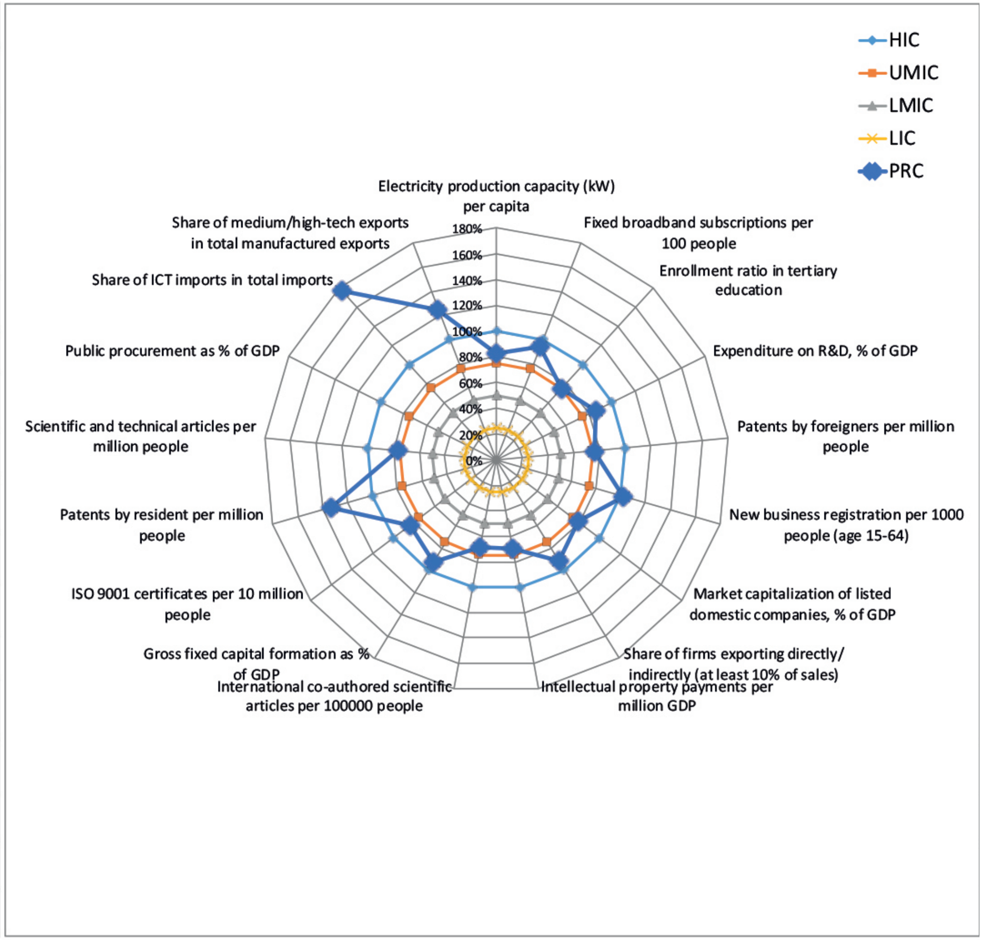
Tool title	Component	Category	Sub-category	Indicator	HIC's average	UMIC's average	LMIC's average	LIC's average	Honduras
System failure framework	Reflexivity failure	Infrastructure	Physical	Electricity production capacity (kW) per capita	8728 (-7%)	4623 (37%)	1041 (26%)	170 (-23%)	1104 (35%)
			Digital	Fixed broadband subscriptions per 100 people	35.79 (37%)	26.13 (213%)	3.68 (273%)	0.47 (713%)	4.01 (265%)
			Knowledge	Enrollment ratio in tertiary education	79 (9.9%)	58 (78.0%)	27 (45.0%)	9 (15.1%)	26 (48%)
		Institution	R&D investment	Expenditure on R&D, % of GDP	2.37 (25%)	1.23 (62%)	0.52 (3%)	n/a	0.04 (-3%)
			IPR protection	Patents by foreigners per million people	560.88 (28%)	89.56 (29%)	18.77 (19%)	1.95 (30%)	32.61 (-7%)
			Business	New business registration per 1000 people (age 15-64)	4,60	6,30	0,44	n/a	8,6
			Finance	Market capitalization of listed domestic companies, % of GDP	1.34 (70%)	0.73 (80%)	0.69 (82%)	n/a	n/a
		Interaction (or Network)	Production	Share of firms exporting directly/ indirectly (at least 10% of sales)	24	15	13	11	11
			Technology	Intellectual property payments per million GDP	7000 (38.4%)	2850 (29.6%)	1540 (30.2%)	83 (-57.9%)	2618 (37%)
			Science	International co-authored scientific articles per 100000 people	113.9 (21.2%)	15.6 (134.4%)	5.8 (133.3%)	2.1 (53.0%)	2 (251%)
		Capability	Production (capacity)	Gross fixed capital formation as % of GDP	22.29 (8.28%)	34.34 (11.4%)	25.31 (-7.9%)	25.27 (0.5%)	
			Production (quality)	ISO 9001 certificates per 10 million people	3402	1727	183	10	163
			Technology	Patents by resident per million people	715.22 (1%)	551.53 (308%)	12.73 (65%)	0.90 (-93%)	0.81 (300%)
			Science	Scientific and technical articles per million people	1192.03 (8%)	323.43 (71%)	87.09 (129%)	8.16 (130%)	4.55 (91%)
	Demand articulation failure	Domestic market	Public sector	Public procurement as % of GDP	14,2	8,7	13,4	7,3	9
			Private sector (domestic)	Share of ICT imports in total imports	14.1 (10.9%)	19.3 (19.0%)	13.3 (86.5%)	2.7 (-31.6%)	5 (-16%)
		Int'l market	Private sector (foreign)	Share of medium/high-tech exports in total manufactured exports	48 (-1.6%)	32 (6.8%)	25 (15.0%)	14 (-28.0%)	24 (-18%)



Source: Authors' elaboration.

Figure 66. Country gap profile: China

Tool title	Component	Category	Sub-category	Indicator	HIC's average	UMIC's average	LMIC's average	LIC's average	PRC
System failure framework	Reflexivity	Infrastructure	Physical	Electricity production capacity (kW) per capita	8728 (-7%)	4623 (37%)	1041 (26%)	170 (-23%)	5858 (72%)
			Digital	Fixed broadband subscriptions per 100 people	35.79 (37%)	26.13 (213%)	3.68 (273%)	0.47 (713%)	33.60 (264%)
			Knowledge	Enrollment ratio in tertiary education	79 (9.9%)	58 (78.0%)	27 (45.0%)	9 (15.1%)	58 (140%)
		Institution	R&D investment	Expenditure on R&D, % of GDP	2.37 (25%)	1.23 (62%)	0.52 (3%)	n/a	1.71 (40%)
			IPR protection	Patents by foreigners per million people	560.88 (28%)	89.56 (29%)	18.77 (19%)	1.95 (30%)	107.97 (55%)
			Business	New business registration per 1000 people (age 15-64)	4,60	6,30	0,44	n/a	
			Finance	Market capitalization of listed domestic companies, % of GDP	1.34 (70%)	0.73 (80%)	0.69 (82%)	n/a	0.83 (203%)
		Interaction (or Network)	Production	Share of firms exporting directly/ indirectly (at least 10% of sales)	24	15	13	11	21
			Technology	Intellectual property payments per million GDP	7000 (38.4%)	2850 (29.6%)	1540 (30.2%)	83 (-57.9%)	2578 (20%)
			Science	International co-authored scientific articles per 100000 people	113.9 (21.2%)	15.6 (134.4%)	5.8 (133.3%)	2.1 (53.0%)	13 (211%)
		Capability	Production (capacity)	Gross fixed capital formation as % of GDP	22.29 (8.28%)	34.34 (11.4%)	25.31 (-7.9%)	25.27 (0.5%)	42.49 (-3.3%)
			Production (quality)	ISO 9001 certificates per 10 million people	3402	1727	183	10	2301
			Technology	Patents by resident per million people	715.22 (1%)	551.53 (308%)	12.73 (65%)	0.90 (-93%)	953.14 (359%)
			Science	Scientific and technical articles per million people	1192.03 (8%)	323.43 (71%)	87.09 (129%)	8.16 (130%)	374.40 (69%)
	Demand articulation	Domestic market	Public sector	Public procurement as % of GDP	14,2	8,7	13,4	7,3	4
			Private sector (domestic)	Share of ICT imports in total imports	14.1 (10.9%)	19.3 (19.0%)	13.3 (86.5%)	2.7 (-31.6%)	25 (23%)
		Int'l market	Private sector (foreign)	Share of medium/high-tech exports in total manufactured exports	48 (-1.6%)	32 (6.8%)	25 (15.0%)	14 (-28.0%)	60 (0.8%)



Source: Authors' elaboration.

6 Examples of policy instruments and their application to policy issues/areas, as identified by the tool

FRAMING AND DESIGNING

► **Is the country capable of establishing and implementing innovation policies to address societal challenges?**

- Which sets of policy capabilities are required to implement innovation policies?
- Which indicators can be used to measure each policy's capabilities?
- How does the country perform globally?
- Capability portfolio and gaps
- Where is the country positioned compared to similar countries?
- By income-level and industry structure (agriculture/manufacturing/trade openness)
- Which policy areas should the country prioritize and improve to facilitate transformative innovation policies?

KEY QUESTIONS

► **Does the country have sufficient reflexivity to monitor, anticipate and adapt to changes and uncertainties?**

Infrastructure/institution/interaction/capabilities

► **Does the country share the goal and direction of the transformation process?**

Regulation and standards/targeted funding, etc. for shared vision, goal and direction

Material efficiency, energy productivity, economic decoupling, use of sustainable energy, competitiveness of sustainable technology and products?

► **Does the country create sufficient spaces for learning about user needs to facilitate the uptake of innovations?**

Public procurement, demand creation for sustainable products

Guided search or directionality can translate into concrete policies. Some recommended policy instruments are listed in Table 7.

Table 7. Individual policy tools that can contribute to systemic instrument goals

GOAL OF SYSTEMIC INSTRUMENTS	EXAMPLES OF INDIVIDUAL INSTRUMENTS
Stimulate and organize participation of relevant actors (1)	Clusters; new forms of public-private partnerships, interactive stakeholder involvement techniques; public debates; scientific workshops; thematic meetings; transition arenas; venture capital; risk capital
Create space for actors' capability development (2)	Articulation discourse; backcasting; foresights; road-mapping; brainstorming; education and training programmes; technology platforms; scenario development workshops; policy labs; pilot projects
Stimulate occurrence of interactions (3)	Cooperative research programmes; consensus development conferences; cooperative grants and programmes; bridging instruments (centres of excellence, competence centres); collaboration and mobility schemes; policy evaluation procedures; debates facilitating decision-making; science shops; technology transfer
Prevent too strong and too weak ties (4)	Timely procurement (strategic, public, R&D-friendly); demonstration centres; strategic niche management; political tools (awards and honours for innovation novelties); loans/guarantees/tax incentives for innovative projects or new technological applications; prizes; constructive technology assessment; technology promotion programmes; debates; discourses; venture capital; risk capital
Secure presence of hard and soft institutions (5)	Awareness-building measures; information and education campaigns; public debates; lobbying, voluntary labels; voluntary agreements
Prevent too weak and too stringent institutions (6)	Regulations (public, private); limits; obligations; norms (product, user); agreements; patent laws; standards; taxes; rights; principles; non-compliance mechanisms
Stimulate physical, financial and knowledge infrastructure (7)	Classical R&D grants, taxes, loans, schemes; funds (institutional, investment, guarantee, R&D), subsidies; public research labs
Ensure adequate quality of infrastructure (8)	Foresights; trend studies; roadmaps; intelligent benchmarking; SWOT (strengths, weaknesses, opportunities and threats) analyses; sector and cluster studies; problem/needs/stakeholders/solution analyses; information systems (for programme management or project monitoring); evaluation practices and toolkits; user surveys; databases; consultancy services; tailor-made applications of group decision-support systems; knowledge-management techniques; technology assessments; knowledge-transfer mechanisms; policy intelligence tools (policy monitoring and evaluation tools, systems analyses); scoreboards; trend charts

Source: Wieczorek and Hekkert (2012).

Once a particular set of policies is put on track, policymakers need to coordinate policies at the systemic level. Weber and Rohracher (2012) point out some possible challenges throughout this process:

- Lack of multi-level policy coordination across different systemic levels (e.g. regional–national–European or between technological and sectoral systems)
- Lack of horizontal coordination between research, technology and innovation policies on the one hand and sectoral policies (e.g. transport, energy, agriculture) on the other
- Lack of vertical coordination between ministries and implementing agencies leads to a deviation between strategic intentions and operational implementation of policies
- No coherence between public- and private-sector institutions
- No temporal coordination, resulting in mismatches related to the timing of interventions by different actors

7 Reference to “outside-the-box” policy solutions

Developing countries should avoid assuming that it is possible to follow in the footsteps of a model country to implement successful industrial innovation policies. Such an assumption may be problematic for at least three reasons:

First, countries follow heterogeneous development paths. Scholarly understandings of policies may imperfectly match policy realities. For example, successful industrialization of East Asian economies—including Japan, Republic of Korea, or Taiwan, Province of China—involved sustained and systematic efforts to create strong national innovation systems through a process driven by active government directives, using innovation policy strategically to achieve development targets from the very early stages of industrialization. Hence, East Asian countries integrated policy remedies addressing system failures early in the developing stage. These experiences contrast with those of the United States where, despite the active presence of government as driver of technological change and innovation, the market failure argument provided the dominant logic for policy formulation. The East Asian experience, while frequently cited as an example of a successful innovation-led industrialization process, was bound in both time and space. It would be extremely difficult to replicate that experience under current global market conditions and dynamics.

Second, the global system is in a continuous state of change: what was possible in the past may be out of scope today. The intensity of globalization has deepened over the past decades, as markets for production, trade, labour and finance were liberalized. At the same time, there is enhanced institutional synchronization around international norms and standards on trade, environmental, economic and labour issues. While the degree and intensity of developing countries’ participation in global production networks is more limited relative to their more industrialized counterparts, developing countries face similar structural challenges regarding environmental, social and governance issues, including climate change and income polarization. Firms in developing countries, often in a dependent position in the global production network, are forced to conform to new standards set by globally leading firms. Thus, they now face so-called “twin challenges” of industrialization and sustainable development (Park et al. 2021). Similarly, the short-term implications of the ongoing COVID-19 pandemic and the disruption of global value chains are exacerbating challenges in developing countries.

Third, policy design and implementation should acknowledge path dependency and heterogeneity across countries. Each country has a particular set of resource endowments, skills, industry structure, culture, scientific and technological knowledge bases, infrastructure, and political systems, among others. All these differences will frame the environment in which policy interventions get implemented, thus making it difficult to achieve intended results by simply replicating a set of successful policy interventions implemented elsewhere.

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Annex I. Cluster analysis results based on manufacturing value added as % of GDP and agriculture, forestry, and fishing value added as % of GDP

Category 1: Countries with the highest value-added portion of the agriculture/forestry/fishing sector and the lowest value-added portion of the manufacturing sector

COUNTRY	REGION	INCOME GROUP
Ethiopia	Sub-Saharan Africa	Low income
Mali	Sub-Saharan Africa	Low income
Niger	Sub-Saharan Africa	Low income
Sierra Leone	Sub-Saharan Africa	Low income
Chad	Sub-Saharan Africa	Low income

Category 2: Countries with intermediate levels of value added in the agriculture/forestry/fishing sector and value added in the manufacturing sector

COUNTRY	REGION	INCOME GROUP
Albania	Europe & Central Asia	Upper middle income
Benin	Sub-Saharan Africa	Lower middle income
Bhutan	South Asia	Lower middle income
Burkina Faso	Sub-Saharan Africa	Low income
Burundi	Sub-Saharan Africa	Low income
Cambodia	East Asia & Pacific	Lower middle income
Cameroon	Sub-Saharan Africa	Lower middle income
Central African Republic	Sub-Saharan Africa	Low income
Congo, Dem. Rep.	Sub-Saharan Africa	Low income
Cote d'Ivoire	Sub-Saharan Africa	Lower middle income
Dominica	Latin America & Caribbean	Upper middle income
Gambia, The	Sub-Saharan Africa	Low income
Ghana	Sub-Saharan Africa	Lower middle income
Guinea	Sub-Saharan Africa	Low income
Guinea-Bissau	Sub-Saharan Africa	Low income
Haiti	Latin America & Caribbean	Lower middle income
India	South Asia	Lower middle income
Kenya	Sub-Saharan Africa	Lower middle income
Kiribati	East Asia & Pacific	Lower middle income
Lao PDR	East Asia & Pacific	Lower middle income
Madagascar	Sub-Saharan Africa	Low income
Marshall Islands	East Asia & Pacific	Upper middle income
Mauritania	Sub-Saharan Africa	Lower middle income
Micronesia, Fed. Sts.	East Asia & Pacific	Lower middle income
Mozambique	Sub-Saharan Africa	Low income
Myanmar	East Asia & Pacific	Lower middle income
Nepal	South Asia	Lower middle income
Nicaragua	Latin America & Caribbean	Lower middle income
Nigeria	Sub-Saharan Africa	Lower middle income
Pakistan	South Asia	Lower middle income
Rwanda	Sub-Saharan Africa	Low income
Senegal	Sub-Saharan Africa	Lower middle income
Tajikistan	Europe & Central Asia	Lower middle income

Tanzania	Sub-Saharan Africa	Lower middle income
Timor-Leste	East Asia & Pacific	Lower middle income
Togo	Sub-Saharan Africa	Low income
Tonga	East Asia & Pacific	Upper middle income
Uganda	Sub-Saharan Africa	Low income
Uzbekistan	Europe & Central Asia	Lower middle income
Vanuatu	East Asia & Pacific	Lower middle income

Category 3: Countries with the lowest value-added portion of the agriculture/forestry/fishing sector and the highest value-added portion of the manufacturing sector

COUNTRY	REGION	INCOME GROUP
Algeria	Middle East & North Africa	Lower middle income
Angola	Sub-Saharan Africa	Lower middle income
Argentina	Latin America & Caribbean	Upper middle income
Armenia	Europe & Central Asia	Upper middle income
Azerbaijan	Europe & Central Asia	Upper middle income
Bangladesh	South Asia	Lower middle income
Belarus	Europe & Central Asia	Upper middle income
Belize	Latin America & Caribbean	Lower middle income
Bolivia	Latin America & Caribbean	Lower middle income
Bosnia and Herzegovina	Europe & Central Asia	Upper middle income
Botswana	Sub-Saharan Africa	Upper middle income
Brazil	Latin America & Caribbean	Upper middle income
Cabo Verde	Sub-Saharan Africa	Lower middle income
China	East Asia & Pacific	Upper middle income
Colombia	Latin America & Caribbean	Upper middle income
Congo, Dem Rep.	Sub-Saharan Africa	Lower middle income
Costa Rica	Latin America & Caribbean	Upper middle income
Cuba	Latin America & Caribbean	Upper middle income
Djibouti	Middle East & North Africa	Lower middle income
Dominican Republic	Latin America & Caribbean	Upper middle income
Ecuador	Latin America & Caribbean	Upper middle income
Egypt	Middle East & North Africa	Lower middle income
El Salvador	Latin America & Caribbean	Lower middle income
Equatorial Guinea	Sub-Saharan Africa	Upper middle income
Eswatini	Sub-Saharan Africa	Lower middle income
Fiji	East Asia & Pacific	Upper middle income
Gabon	Sub-Saharan Africa	Upper middle income
Georgia	Europe & Central Asia	Upper middle income
Guatemala	Latin America & Caribbean	Upper middle income
Honduras	Latin America & Caribbean	Lower middle income
Indonesia	East Asia & Pacific	Lower middle income
Iran, Islamic Rep.	Middle East & North Africa	Lower middle income
Iraq	Middle East & North Africa	Upper middle income
Jamaica	Latin America & Caribbean	Upper middle income
Jordan	Middle East & North Africa	Upper middle income

Kazakhstan	Europe & Central Asia	Upper middle income
Kosovo	Europe & Central Asia	Upper middle income
Kyrgyz Republic	Europe & Central Asia	Lower middle income
Lebanon	Middle East & North Africa	Upper middle income
Lesotho	Sub-Saharan Africa	Lower middle income
Malaysia	East Asia & Pacific	Upper middle income
Maldives	South Asia	Upper middle income
Mauritius	Sub-Saharan Africa	Upper middle income
Mexico	Latin America & Caribbean	Upper middle income
Moldova	Europe & Central Asia	Upper middle income
Mongolia	East Asia & Pacific	Lower middle income
Montenegro	Europe & Central Asia	Upper middle income
Morocco	Middle East & North Africa	Lower middle income
Namibia	Sub-Saharan Africa	Upper middle income
North Macedonia	Europe & Central Asia	Upper middle income
Panama	Latin America & Caribbean	Upper middle income
Paraguay	Latin America & Caribbean	Upper middle income
Peru	Latin America & Caribbean	Upper middle income
Philippines	East Asia & Pacific	Lower middle income
Romania	Europe & Central Asia	Upper middle income
Russian Federation	Europe & Central Asia	Upper middle income
Samoa	East Asia & Pacific	Lower middle income
Serbia	Europe & Central Asia	Upper middle income
South Africa	Sub-Saharan Africa	Upper middle income
South Sudan	Sub-Saharan Africa	Low income
Sri Lanka	South Asia	Lower middle income
Suriname	Latin America & Caribbean	Upper middle income
Thailand	East Asia & Pacific	Upper middle income
Tunisia	Middle East & North Africa	Lower middle income
Turkey	Europe & Central Asia	Upper middle income
Ukraine	Europe & Central Asia	Lower middle income
Vietnam	East Asia & Pacific	Lower middle income
West Bank and Gaza	Middle East & North Africa	Lower middle income
Yemen	Middle East & North Africa	Low income
Zambia	Sub-Saharan Africa	Lower middle income
Zimbabwe	Sub-Saharan Africa	Lower middle income

Annex II. Results of analysis of number of international co-authored scientific articles

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Afghanistan	57	70	61	88	79	114	154	187	246	240	437
Albania	127	156	188	209	248	264	287	380	373	491	610
Algeria	1,752	1,937	2,236	2,383	2,701	3,143	3,530	3,811	3,991	4,188	4,975
American Samoa	8	6	10	17	13	7	9	17	9	14	11
Andorra	8	8	15	20	22	23	15	16	27	29	34
Angola	47	65	59	85	93	99	137	106	138	150	156
Anguilla	2	2	6	5	10	16	15	17	8	18	13
Argentina	4,722	5,098	5,147	5,595	5,835	6,132	6,252	6,718	6,872	8,009	8,396
Armenia	542	698	620	632	684	734	773	847	931	781	881
Aruba	12	5	5	17	9	19	10	6	18	23	30
Australia	31,207	35,069	39,724	43,012	46,962	51,171	55,254	59,792	63,838	68,724	75,722
Austria	11,614	12,702	13,640	14,259	15,230	16,170	16,927	17,903	18,684	20,096	22,522
Azerbaijan	358	397	336	342	413	521	526	660	725	857	895
Bahamas	25	29	32	41	41	33	73	67	85	86	109
Bahrain	182	174	257	232	243	306	327	421	583	691	1,075
Bangladesh	1,272	1,571	1,692	2,038	2,054	2,328	2,944	3,155	4,033	5,206	7,670
Barbados	73	86	78	79	78	85	89	101	118	119	145
Belarus	919	994	987	1,055	1,096	1,246	1,417	1,574	1,715	1,704	1,716
Belgium	16,250	17,382	18,550	19,843	21,200	21,964	22,681	24,335	24,190	26,150	29,175
Belize	19	19	32	26	32	26	37	38	38	50	78
Benin	238	283	329	343	357	349	430	444	470	528	729
Bermuda	33	40	48	30	38	40	51	44	62	61	63
Bhutan	43	29	50	71	71	86	92	88	124	174	197
Bolivia	215	213	242	271	279	294	264	341	369	418	520
Bosnia and Herzegovina	374	401	393	440	538	589	740	816	820	936	1,175
Botswana	236	222	277	320	304	445	443	575	616	652	755
Brazil	13,155	14,739	16,622	18,905	20,992	23,941	25,430	27,844	29,309	32,455	36,324
Brunei Darussalam	67	114	169	207	277	353	365	373	440	539	652
Bulgaria	1,740	1,828	1,910	1,965	1,915	2,246	2,482	2,574	2,478	2,745	2,880
Burkina Faso	317	378	338	391	452	480	482	560	552	590	699
Burundi	25	29	34	37	50	49	58	82	74	114	115
Cambodia	191	212	239	275	313	384	414	451	493	529	561
Cameroon	591	631	738	808	855	961	1,103	1,225	1,308	1,566	1,844
Canada	39,917	43,939	46,465	49,031	51,140	54,371	56,412	60,569	63,712	67,830	74,437
Central African Republic	28	38	31	38	37	56	44	64	49	71	73
Chad	26	23	27	32	36	43	58	50	62	67	102
Chile	4,078	4,663	5,082	6,198	6,715	7,845	8,049	9,174	9,731	11,317	12,393
China	57,761	64,814	75,743	85,590	96,175	107,585	121,254	140,840	161,357	176,623	188,770
Colombia	2,617	3,071	3,374	3,767	4,229	4,770	5,602	6,339	6,881	8,062	8,981
Comoros	9	5	9	7	7	20	13	21	19	21	21

Congo	203	244	293	346	353	389	378	443	403	408	422
Costa Rica	461	488	529	637	636	683	806	879	929	1,095	1,243
Croatia	1,893	2,131	2,124	2,332	2,530	2,675	2,991	3,338	3,530	3,835	4,363
Cuba	884	1,001	988	1,019	984	1,040	1,039	1,209	1,220	1,262	1,339
Curacao	-	-	-	1	-	1	-	-	8	38	36
Cyprus	998	1,143	1,286	1,238	1,359	1,585	1,764	2,044	2,263	2,812	3,409
Czech Republic	6,244	6,904	7,642	8,816	9,605	10,059	10,961	11,706	12,558	13,799	15,062
Côte d’Ivoire	200	228	215	246	279	298	343	445	471	527	663
Democratic Republic Congo	34	53	43	35	70	94	152	152	238	403	604
Denmark	10,949	12,073	13,139	14,363	15,790	17,015	17,856	19,321	19,988	21,767	23,734
Djibouti	14	20	16	19	15	21	18	20	19	33	69
Dominica	22	20	29	23	37	39	35	30	29	22	31
Dominican Republic	74	76	105	87	122	132	145	186	238	333	379
Ecuador	397	500	606	797	1,307	1,768	2,486	2,854	3,287	3,600	3,832
Egypt	4,423	5,320	6,603	7,478	8,257	9,167	9,722	11,049	13,074	16,985	21,961
El Salvador	63	65	54	79	105	106	80	92	91	106	159
Equatorial Guinea	8	9	9	17	17	24	15	21	19	13	27
Eritrea	24	8	23	24	25	26	35	38	37	43	65
Estonia	1,127	1,264	1,444	1,550	1,649	1,908	2,016	2,250	2,643	2,712	3,178
Ethiopia	663	719	906	1,077	1,205	1,398	1,850	2,068	2,515	3,070	4,354
Fiji	113	133	152	176	186	230	268	316	327	419	440
Finland	8,812	9,715	10,561	11,274	11,894	12,552	12,851	13,351	14,354	15,074	16,588
France	50,676	54,324	57,870	60,067	62,608	65,418	67,942	69,897	70,697	73,211	76,107
French Guiana	40	64	65	68	77	97	70	93	104	133	109
French Polynesia	63	97	66	85	104	148	109	138	143	157	174
Gabon	135	113	137	167	167	169	172	181	190	181	269
Gambia	90	129	139	154	168	175	191	146	197	229	302
Georgia	493	584	606	608	782	987	1,088	1,393	1,625	1,520	1,508
Germany	67,103	72,289	76,185	78,595	82,985	86,988	90,246	94,308	96,504	101,282	109,999
Ghana	541	688	782	944	1,111	1,352	1,569	1,948	2,275	2,748	3,457
Greece	7,243	7,907	8,355	8,762	9,232	9,784	10,273	10,846	11,239	11,902	13,444
Greenland	76	104	103	104	127	104	97	121	131	130	161
Grenada	77	105	110	137	133	134	210	227	206	240	286
Guadeloupe	55	62	90	101	75	74	51	58	57	66	92
Guam	33	37	41	34	26	26	38	44	39	64	58
Guatemala	109	169	173	168	240	239	260	250	284	359	426
Guinea	36	37	35	51	106	116	130	95	119	136	174
Guinea Bissau	30	35	36	57	40	60	60	60	58	59	69
Guyana	17	24	22	22	29	38	33	46	53	75	80
Haïti	48	48	79	95	107	105	122	96	115	136	147
Honduras	68	75	80	70	89	76	121	163	188	343	284
Hong Kong SAR, China	9,886	10,702	11,488	12,440	13,218	14,170	15,531	17,093	18,478	19,468	23,048
Hungary	4,398	4,851	4,856	5,161	5,241	5,646	5,809	6,204	6,412	6,788	7,708

Iceland	828	937	999	1,045	1,133	1,295	1,330	1,408	1,476	1,473	1,647
India	15,609	17,309	19,011	20,795	22,456	25,015	26,945	31,158	35,120	41,726	54,262
Indonesia	1,741	2,124	2,456	2,746	2,948	3,602	4,414	6,082	7,734	8,934	10,260
Iran, Islamic Rep. of	6,604	7,284	8,245	8,829	9,335	10,524	12,445	14,484	17,685	21,954	26,007
Iraq	372	545	958	1,225	1,385	1,705	2,240	3,002	3,799	4,740	5,424
Ireland	6,054	6,363	6,893	7,218	7,465	8,396	8,877	9,632	10,212	11,356	13,263
Israel	8,191	8,501	8,746	9,142	10,002	10,310	10,530	11,487	11,689	12,511	13,566
Italy	35,313	39,158	42,671	45,563	49,135	52,041	55,256	58,942	61,282	68,184	74,219
Jamaica	154	189	187	207	234	232	229	265	260	357	382
Jersey	0	-	-	-	-	-	-	1	-	-	1
Jordan	1,006	1,157	1,108	1,219	1,344	1,573	1,739	2,271	2,713	3,395	4,555
Kazakhstan	260	389	637	906	1,094	1,441	1,755	2,113	2,897	3,056	3,512
Kenya	1,429	1,511	1,780	1,952	2,001	2,227	2,478	2,658	2,994	3,448	4,142
Kiribati	-	0	5	9	6	6	7	5	14	17	10
Korea, Rep.	17,199	18,846	19,904	20,763	21,811	22,643	23,213	24,978	26,589	29,190	32,358
Kuwait	549	583	659	729	777	909	1,025	1,153	1,431	1,616	2,042
Kyrgyzstan	71	78	125	112	133	153	191	254	295	415	464
Lao PDR	142	194	183	192	243	255	235	291	326	320	337
Latvia	493	482	550	600	738	891	1,019	1,092	1,190	1,425	1,589
Lebanon	884	1,088	1,266	1,431	1,552	1,829	2,026	2,250	2,470	2,925	3,188
Lesotho	27	30	26	30	36	33	38	43	67	79	99
Liberia	19	19	28	31	61	86	83	94	114	72	121
Libya	200	235	303	348	354	320	378	429	469	552	790
Liechtenstein	74	90	90	114	109	114	111	125	125	115	140
Lithuania	989	1,067	1,132	1,307	1,420	1,551	1,791	2,062	2,237	2,572	2,826
Luxembourg	848	999	1,180	1,416	1,462	1,520	1,611	1,773	1,860	1,928	2,264
Macao SAR, China	460	696	896	1,104	1,388	1,841	2,007	2,208	2,220	2,604	3,503
Macedonia	302	342	351	424	453	485	548	576	623	670	767
Madagascar	195	221	258	228	272	269	318	322	319	382	461
Malawi	336	363	368	427	494	598	678	742	774	922	1,121
Malaysia	6,251	7,422	8,595	10,086	10,445	11,355	12,478	13,787	15,795	18,196	21,716
Maldives	13	19	12	19	24	20	33	34	43	89	84
Mali	176	202	194	174	234	243	279	276	319	334	354
Malta	167	236	297	330	387	436	531	588	579	661	818
Martinique	30	35	38	41	45	55	44	45	40	58	50
Mauritania	28	33	39	42	37	52	46	63	66	75	108
Mauritius	73	102	124	116	126	143	208	222	318	316	352
Mayotte	9	4	2	5	1	3	5	4	7	12	5
Mexico	6,692	7,237	7,649	8,199	8,482	9,427	10,236	11,071	11,901	13,552	15,009
Moldova	255	257	262	295	274	371	329	327	364	388	394
Monaco	90	96	118	96	124	149	165	169	229	242	265
Mongolia	198	261	310	296	295	359	410	470	571	622	717
Montenegro	144	175	203	235	209	259	313	308	365	461	446
Morocco	1,344	1,618	1,659	1,901	2,000	2,293	2,486	2,657	3,110	3,722	4,605
Mozambique	193	190	215	240	312	369	418	461	516	619	767
Myanmar	76	81	79	105	162	235	340	451	545	779	737
Namibia	113	150	178	210	254	284	327	378	370	436	535
Nepal	406	490	575	657	769	856	1,031	1,070	1,287	1,711	2,076

Netherlands	25,975	29,391	30,850	32,056	33,794	35,867	37,741	39,973	41,058	43,700	48,184
New Caledonia	85	140	139	165	175	172	158	169	176	184	190
New Zealand	6,478	6,893	7,579	7,849	8,097	8,724	9,364	10,115	10,643	11,100	12,185
Nicaragua	90	105	85	81	106	118	139	125	129	147	131
Niger	94	95	89	121	175	153	138	167	186	188	217
Nigeria	1,274	1,381	1,569	2,065	2,302	2,926	3,466	4,302	5,543	6,754	8,485
Korea, Dem People's Rep of	29	86	17	34	64	74	87	87	101	86	88
Norway	8,453	9,667	10,208	11,032	11,746	13,329	14,110	15,028	15,703	17,321	19,292
Oman	587	653	743	828	999	1,162	1,159	1,414	1,669	2,000	2,748
Pakistan	3,049	3,698	4,537	5,060	5,850	7,110	8,836	10,824	13,503	17,635	23,428
Palau	7	10	13	9	16	12	21	18	28	24	29
Palestine	201	255	318	377	355	400	520	567	661	797	1,055
Panama	319	417	420	436	456	494	537	598	692	716	840
Papua New Guinea	112	120	112	143	155	174	159	181	200	227	264
Paraguay	85	91	107	116	148	182	224	211	312	364	380
Peru	854	931	1,028	1,195	1,383	1,577	1,758	1,982	2,357	3,200	3,763
Philippines	894	975	1,107	1,181	1,360	1,473	1,690	1,765	2,019	2,516	3,119
Poland	9,113	10,025	11,067	11,992	12,999	14,240	15,517	16,756	17,881	20,367	22,935
Portugal	8,384	9,622	10,693	11,121	12,127	13,137	13,680	14,957	15,851	17,354	19,232
Puerto Rico	630	614	566	555	525	598	585	578	606	662	779
Qatar	667	953	1,480	2,169	2,713	3,193	3,215	3,285	3,530	3,975	4,671
Romania	3,682	4,180	4,592	4,708	4,952	5,299	5,414	5,735	6,096	6,735	7,349
Russian Federation	12,187	12,726	14,081	15,325	17,458	19,305	21,491	23,585	25,894	28,563	29,625
Rwanda	144	161	209	239	284	324	372	453	490	688	893
Samoa	21	11	16	21	14	19	29	30	37	64	86
San Marino	9	18	26	17	25	27	32	34	46	41	51
Saudi Arabia	5,777	8,093	10,091	12,524	14,664	15,688	16,058	17,312	20,201	27,121	37,246
Senegal	402	467	475	485	581	578	620	676	678	761	803
Serbia	2,083	2,688	2,713	2,934	3,064	3,259	3,614	3,840	4,342	4,422	5,256
Sierra Leone	37	42	47	67	106	149	158	161	167	210	278
Singapore	8,544	9,705	10,786	11,604	12,611	13,250	14,235	15,137	16,010	17,426	18,633
Slovakia	2,329	2,522	2,540	3,010	3,134	3,611	3,850	3,971	4,378	4,857	5,016
Slovenia	2,199	2,547	2,671	2,671	2,957	3,126	3,230	3,481	3,568	3,930	4,530
Somalia	8	6	11	19	18	15	37	25	60	75	105
South Africa	5,990	6,925	7,804	8,770	9,598	10,916	12,091	13,147	14,421	15,986	18,267
South Sudan	3	-	2	15	8	14	16	22	20	41	68
Spain	31,303	34,599	36,852	39,348	41,295	44,167	46,188	48,818	51,047	56,305	61,035
Sri Lanka	441	557	620	713	809	954	1,108	1,209	1,352	1,557	1,932
Sudan	307	348	470	488	525	601	641	775	905	1,079	1,452
Suriname	9	20	28	17	31	59	39	52	67	58	65
Swaziland	65	60	67	77	90	89	113	129	136	142	145
Sweden	17,274	19,239	20,665	22,023	23,901	25,847	27,088	28,618	29,728	31,031	33,918
Switzerland	22,729	24,866	26,574	27,843	29,736	31,168	33,063	34,415	34,759	37,585	41,708
Syrian Arab Republic	277	330	314	256	218	230	203	215	276	364	480

Taiwan, Province of China	8,667	9,291	9,986	10,202	10,741	11,303	12,150	12,992	14,434	17,037	19,417
Tajikistan	57	67	74	67	85	84	103	120	182	281	244
Tanzania	711	778	900	1,047	1,135	1,210	1,339	1,435	1,649	1,819	2,077
Thailand	4,003	4,470	4,741	5,201	5,437	6,160	6,741	7,496	8,050	9,383	11,185
Timor-Leste	4	16	12	23	25	29	36	43	34	41	50
Togo	74	68	78	105	118	128	112	159	166	184	216
Tonga	11	5	5	8	10	12	19	21	15	32	22
Trinidad and Tobago	217	194	195	220	214	209	226	241	256	284	334
Tunisia	2,325	2,484	2,722	3,113	3,654	4,163	4,431	4,587	4,604	4,910	5,583
Turkey	5,866	6,901	7,651	7,866	8,964	10,130	10,293	11,056	12,251	14,976	18,406
Turkmenistan	26	39	10	26	15	10	10	8	13	8	24
Turks and Caicos Islands	1	2	5	3	6	7	4	5	3	10	6
Tuvalu	-	1	1	6	1	3	4	3	2	2	1
Uganda	813	896	940	1,093	1,164	1,297	1,509	1,564	1,694	1,999	2,468
Ukraine	3,246	3,309	3,633	3,850	3,953	4,229	4,619	5,179	6,012	6,368	6,510
United Arab Emirates	1,526	1,824	2,056	2,307	3,088	3,704	4,298	4,953	6,219	7,602	10,195
United Kingdom	72,951	80,220	87,779	91,859	99,147	106,123	113,150	120,065	124,418	133,455	148,655
United States	166,126	181,333	193,744	202,707	214,534	226,005	237,272	250,799	256,561	265,895	280,024
United States Minor Outlying Islands	-	1	5	-	3	-	0	2	0	-	-
Uruguay	679	698	755	914	952	1,007	1,051	1,211	1,278	1,375	1,627
Uzbekistan	284	254	287	281	233	317	327	361	531	829	1,016
Vanuatu	21	14	23	27	30	39	30	25	38	44	53
Vatican City State	4	2	1	1	2	2	1	6	8	5	9
Venezuela	894	855	901	955	930	962	1,094	1,117	1,126	1,096	1,128
Viet Nam	1,624	2,124	2,513	2,761	3,069	3,734	4,533	5,880	8,326	11,519	11,074
Virgin Islands (British)	14	6	8	8	3	7	6	3	6	7	10
Virgin Islands (U.S.)	3	7	5	11	7	5	8	14	8	12	23
Wallis and Futuna	1	-	2	-	2	-	1	-	2	3	1
Western Sahara	-	-	-	-	0	-	-	-	-	-	1
Yemen	202	241	284	290	270	321	412	488	645	974	1,483
Zambia	255	291	353	396	429	510	566	552	585	751	878
Zimbabwe	267	323	337	432	427	553	674	758	745	890	1,109

Source: Authors’ elaboration based on www.scival.com.

UNITED NATIONS
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