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ABSTRACT:
Recent years have witnessed a resurgence of industrial policies globally. Through various industrial policy instruments, governments make critical scientific and technological choices that shape innovation paths and resource allocations. Our paper explores innovation capabilities as essential drivers of competitive outcomes, spanning science, technology, and production domains. Based on the economic complexity literature, we propose a methodological framework to measure the innovation capabilities empirically, leveraging data on scientific publications, patents, and trade. Our findings highlight the multidimensional nature of innovation capabilities and underscore the importance of understanding both the specialization and quality of these capabilities. Our results are in line with the complexity literature, as we also find: (i) positive correlations between the innovation complexity and economic growth; and, (ii) the predictive power of existing innovation capabilities for fostering new ones. Based on these findings, we propose novel indicators informing innovation policymaking on the innovation potential across science, technology, and production fields of an ecosystem. We suggest that innovation policymaking needs to be informed by deeper insights into innovation capabilities that are crucial for long-term growth and competitiveness improvement.

Keywords: Innovation capabilities; Complexity metrics; Innovation ecosystems; Science and technology policy; Industrial policy; Economic development; Smart specialization
JEL Codes: O25; O31; O33; O30; O11; O14

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1 INTRODUCTION

Recent years have seen a resurgence of industrial policies worldwide. These policies have mostly been driven not by new insights into their efficacy but by governments responding to challenges such as climate change, supply chain disruptions and national security concerns. In part, these recent industrial policies reveal governments' expectations about which industrial activities will offer long-term benefits to their economies.

By employing a range of industrial policy instruments, governments are also making (explicitly or implicitly) a wide range of scientific and technological choices. These choices shape the economic incentives of any stakeholder – individual or institutional – to facilitate the generation, acquisition, and diffusion of new scientific, technological, and productive knowledge. As a result, industrial policies influence the innovation path of a region or country by allocating human and financial resources through a range of public policy instruments. Successful industrial policies will aim to develop new capabilities, nurture nascent ones, and maintain existing advantages on others.

Innovation capabilities represent, in essence, the ability of a country to deliver competitive outputs in a certain field of the innovation process. In many cases, these include skills and knowledge that are embedded in tools, procedures or computer codes that can be easily shared or shipped around the world. However, often these are tacit, meaning that they are embedded in individuals but are not easily codifiable and, hence, not easily transferrable. The fact that these are not easily transferrable makes their understanding and measurement crucial for innovation policymaking.

But what are the right scientific- or technological-related capabilities to target with industrial policies? For instance, which fields of scientific research should government funding prioritize? Which promising embryonic technology should get government funding to achieve commercial viability? Answering these questions is not straightforward. They involve the conviction that supporting a nascent local industry today will generate critical input for other local industries at competitive prices in the future or that it will generate substantial spillover benefits to the local economy. Market mechanisms often provide incomplete signals to inform such decisions. Evaluating the benefits and costs of these interventions will be crucial in the evolving landscape of industrial policy.

Innovation is a multidimensional force that fuels progress, economic growth, and competitiveness. It encompasses various facets of human endeavor across nations, regions, and industries Among the many relevant dimensions of innovation are the people and institutions related to the production of science, technologies, and products. An effective innovation ecosystem thrives on fostering robust interactions between its scientific, technological, and productive stakeholders. These three interdependent sub-ecosystems can characterize the landscape of innovation ecosystems worldwide. However, the complexity of such capabilities varies, necessitating a nuanced approach to harnessing the unique strengths of each ecosystem.

Our empirical approach focuses on these three dimensions of science, technologies, and products. On the macro level, advanced national economies typically perform in all these three dimensions. Yet these economies may greatly differ in the specialization, intensity and combination of these dimensions and the subcategories within them. Some economies excel in scientific research but struggle to translate scientific outcomes into technological advances, leading to untapped potential. Others might exhibit exceptional ingenuity in one technological field yet face challenges in transforming these advances into commercially viable products.

We develop a method focusing on innovation capabilities as measured by the scientific, technological, and productive know-how – tacit or codifiable – existing in each country or region. Assessing the capabilities of these three dimensions is crucial for evidence-based policymaking but is not straightforward. Our paper provides a novel empirical analysis of the current set of innovation capabilities in economies for international comparison. This relies on a corpus of economic literature that focuses on economic and technological relatedness and complexity that is applied to data on scientific publications, patent applications and international trade.

The remainder of this paper is structured as follows. Section 2 summarizes the literature surrounding this topic, introducing the concepts of complexity and relatedness, amongst others. Section 3 defines innovation capabilities, discusses how they can be measured, and describes the data used in the paper. Section 4 explores the qualitative differences of innovation capabilities by introducing the concept of innovation complexity. Section 5 sheds light on how current capabilities can be leveraged to develop new ones. The last section concludes the paper with the main takeaways, limitation remarks, and further research.

2 MOTIVATION AND LITERATURE REVIEW

The path to successful and innovative products can be traced all the way back to some technological and scientific capabilities. Some of the most advanced innovations originated from basic, exploratory science. Indeed, scientific breakthroughs can open the door for ground-breaking capabilities, giving birth to new technological solutions that boost economic growth and, more importantly, assist in addressing societal challenges. The scientific and technological discoveries of penicillin and semiconductors, for instance, led to groundbreaking innovations. These first boosted direct growth in the health and electronics industries, respectively; and later spread productivity growth across the economy (WIPO, 2015).[1]

A relatively linear path from scientific discovery and technological development to industrial production is still noticeable in today's medical innovations, such as new medicines and medical implants. Typically, a new pharmaceutical product in the market can be linked to a scientific finding of a molecule and subsequent technologies to synthetize it at scale. The same applies to advanced medical implants – such as pacemakers and artificial organs – which result from the synergy of scientific understanding of human biology and technological capabilities in materials engineering and miniaturized electronics.

However, mastering scientific capabilities does not necessarily lead to product and process innovation, for several reasons. First, scientists may lack the incentives to link with other actors because innovation is not their primary goal. Second, scientific capabilities can be very theoretical and not easily applicable when related to the most fundamental science. Third, the specific settings of scientific institutions – such as organizational practices and culture – may differ considerably from private ones, leading to barriers in establishing science-industry linkages.

Similarly, not all technologies develop all the way to goods and services commercialized in the market. For instance, studies based on surveys of applicants find that between a half and a third of patents are never used commercially. Using an extensive Pat-Val survey, Torrisi *et al* (2016) and Giuri *et al* (2007) find that between a third and a half of the surveyed patents are used only strategically or not used at all. Other studies find even lower results due to other regulations – such as medicine approval – preventing patented products from being commercialized.

[1] The World IP Report 2015 provides a discussion on the discovery and development of penicillin and semiconductors and their contribution to economic growth (WIPO, 2015).

Moreover, several technologies are created from other technological capabilities without requiring the related scientific capabilities. Technological advances can stem from creative combinations and applications of existing tools and concepts. For instance, 3D printing, or additive manufacturing, is a technology that has evolved significantly in recent years. However, the basic principles have been known for decades. Innovations in 3D printing often involve the development of new materials and refining the printing process rather than groundbreaking scientific advancements. This technology is widely used for rapid prototyping in various industries, allowing for quick and cost-effective production of prototypes and customized products.

In addition, a country or a company does not need to master all the scientific and technological capabilities required to successfully develop new productive capabilities. Indeed, skilled workers often acquire productive capabilities by systematically using advanced equipment rather than through formal scientific or engineering training. This is known in the economic literature as *learning by doing*. Arrow (1962) suggests that learning is the product of experience and, hence, hypothesizes that innovation (technical change) can be related to experience. He defines experience as "…the very activity of production which gives rise to problems for which favorable responses are selected over time."

These innovation capabilities do not float in a vacuum. They are embedded as tacit knowledge in individuals and organizations that facilitate the generation, acquisition, and diffusion of new scientific, technological, and productive outputs. These innovation stakeholders include firms and academic institutions (such as universities and public research organizations). They also include public institutions without a primary scientific or technological mission, such as government agencies, financial institutions, and intellectual property (IP) offices. The collection of all these stakeholders in a country, region or industry defines a living "innovation ecosystem".[2]

Hidalgo and Hausmann (2009) designed the complexity indicator with the goal to measure the levels of know-how embedded into innovation ecosystems. Computing the complexity indicator involves an iterative process considering both how each country specializes in each capability and how many countries specialize in each capability. In other words, complex capabilities are those that are rare and only diversified innovation ecosystems can make use of them. Conversely, complex innovation ecosystems are those that specialize in capabilities that are rare and in which only other diversified innovation ecosystems are specialized.

[2] For an introduction to the notion of innovation ecosystems and the strands of the economic and social sciences literature discussing it, see Chapter 1 of WIPO (2022).

Conceptually, complexity can rank countries based on the level of sophistication of their capabilities. High-complexity countries are specialized in the most complex capabilities.

Economic literature has found a strong relationship between complexity and economic performance. First, not only are developed nations more diversified but they are also more complex. Vibrant innovation ecosystems can generate elaborate and unique technologies that lead to the creation of complex products. Second, studies find that economies attaining technologically complex productive structures typically see higher economic performance. Countries with higher complexity are also more likely to have future economic growth. Indeed, these more complex economies are more likely to be resilient, by observing longer-run patterns of economic performance. Moreover, the reward of higher complexity goes beyond economic growth, as higher complexity is found to correlate with less inequality, lower green-house-gas emissions, and more economic development.

As a result, the complexity literature views economic development as a structural transformation process. Countries grow by transforming their productive structure from one dominated by low-tech, ubiquitous activities to a more advanced structure with rarer outputs. Additionally, countries with higher complexity measures have a strong predictable pattern of economic growth. Countries that have high complexities relative to their income level grow faster than those that underperform in terms of complexity (Hausmann *et al*, 2024; Hidalgo, 2021; Balland and Rigby , 2017; Hidalgo and Hausmann, 2009). Mewes and Broekel (2022) find that technological capabilities (and their complexity) are a strong predictor of economic growth for European NUTS 2 regions from 2000 to 2014. In effect, they estimated that a 10 percent increase in complexity is associated with 0.45 percent increase in GDP per capita growth. Hidalgo *et al.* (2022) find that economic complexity correlates with higher economic growth, less inequality, less greenhouse gas emissions and more economic development.

Country dynamics have very different patterns: those economies with lower complexity measures have a more turbulent economic growth path. Using the *fitness* metric – a metric equivalent to Hidalgo and Hausmann’s complexity – Cristelli *et al* (2015) find that the predictive power of fitness to explain economic growth depends on the level of the former. Economies with a lower fitness will have a “chaotic” path to growth, whereas those with a higher complexity will have a “laminar” (i.e., more predictive) path to growth.

Still, some caution is needed when interpreting these results, as in most cases economic research has found a strong correlation without a strong empirical setting to test causation (Kogler *et al*, 2023).

How can countries choose which capabilities to pursue? Across the years, there have been several unsuccessful efforts made by policymakers to "recreate Silicon Valley" in their respective regions and states (WIPO, 2019) . The famous Californian hotspot was a small rural community at the beginning of the 20th century and is now globally recognized as a major hub for technology and innovation, making it one of the places in the world with the most diverse and complex know-how. This success story resonates heavily in policymaking. However, other economies may not be able to replicate the multiple factors that made it happen.

Looking to develop high-complexity technologies where there are no solid foundations is like building a palace on an iceberg. Not only it will be hard to build, but its inhospitable environment will make it hard to maintain and access. With no visitors around it, and nobody to fix it, the structure will surely be abandoned and crumble at some point.

Knowledge gets incrementally diversified as it expands. Schools, for instance, start by teaching fundamental concepts such as mathematics and language in the early years of education and later introduce physics, chemistry, literature and foreign languages. Some capabilities are building blocks or platforms to develop new ones. In this sense, innovation capabilities can be considered as a network where similar forms of knowledge connect to each other.

2.1 Using the complexity approach to design *Smart specialization* strategies

In many respects, identifying the relatedness and complexity of the top countries and regions of the world – such as Silicon Valley, Boston or Munich – is relatively straightforward. These regions already have highly functioning innovation ecosystems that lead the way in transforming ideas into science and technologies that nurture the complex products of today and the future.

However, understanding the potential specialization and diversification strategies based on relatedness and complexity tools can be extremely important for the design of innovation-policies for middle-income economies and less developed regions. Smart specialization is an industrial and innovation framework that aims to illustrate how public policies, framework conditions and especially R&D and innovation investment policies can influence the economic, scientific and technological specialization of a region and consequently its productivity, competitiveness and economic growth path (OECD, 2013).

Companies or regions differ in their production capabilities; hence, the direction they should follow will vary accordingly. Innovation economists therefore advocate for countries and regions to pursue smart specialization strategies. These strategies aim to encourage investments that complement the local existing productive or technological assets to create future local capability and competitive advantages (WIPO, 2019). Given the importance of priority selection in smart specialization strategies and regional innovation policy more broadly, scholars assert that there is a need to develop better tools to inform regions' priority choices (Deegan *et al*, 2021; Marrocu *et al.*, 2023). In other words, how can policy makers prioritize technologies or industries when designing innovation and industrial policies that build on their local innovation ecosystem?

Some of these regions are increasingly able to produce scientific research at the international level but fail to transform this research into patented technologies (WIPO, 2019). Conversely, some regions may develop technologies without the related scientific capabilities (Balland and Boschma, 2022).

Despite not being able to contribute scientific outputs, other regions can contribute to international trade but fail to transform that productive capacity into the technological learning that leads to innovation. Such economies and regions can benefit greatly from any guidance on where to focus their limited resources to clear the innovation roadblocks between science, technologies and production. This guidance could also inform what role the IP system can play in assisting innovation policies.

Economists are increasingly suggesting that the complexity and relatedness framework is a useful toolbox to inform innovation policymaking, notably to support smart specialization policies. Balland *et al* (2019) define their smart specialization policy framework as four quadrants summarizing the cost–benefit trade-off of prioritizing the specialization in a given technology instead of another one.

In this approach, an attractive smart specialization policy will prioritize potential technologies with high relatedness and high complexity (low risk and high reward) and oppose the 'dead-end' policy scenario of prioritizing low relatedness and low complexity (high risk and low reward). Additionally, they describe a risky but potentially high-benefit strategy of developing new technologies from scratch (low relatedness but high complexity). Last, they indicate a 'slow-road' policy where there is relatively low-risk but also low reward (high relatedness but low complexity).

By combining these metrics, policymakers can understand which capabilities countries or regions have and how rewarding they are in terms of complexity. Additionally, policymakers can explore which of the not-yet-developed capabilities can be more easily attained given the pre-existing capabilities.

3 IDENTIFYING INNOVATION CAPABILITIES

Following Pugliese *et al* (2019) and Stojkoski *et al* (2023) our proposed methodology measures innovation capabilities by including three different dimensions: scientific, technological and production capabilities.

Scientific, technological, and productive capabilities have their own consistency, yet they are also interdependent in generating innovative ideas, technologies, and products. The sophistication and interconnectedness of these dimensions characterize the innovation ecosystem of a given country, region, or city.

How can these three capability dimensions be measured? Typically, economic literature estimates these capabilities by using a different set of outputs for each dimension. Peer-reviewed scientific publications reflect advances in science, whether incremental or breakthrough discoveries, as they are a tangible, credible and easy-to-disseminate source of new scientific information. Patent applications capture the exclusivity requests for new technologies – either methods, products, or both – that are novel and have an industrial application. Like scientific publications, the patent application process requires public disclosure and therefore facilitates the dissemination of technical information. Last, exports are considered to indicate a country's ability to provide competitive goods and services, implying that there is an efficient mechanism behind their production.

3.1 Innovation capability related data

We make use of three datasets to measure innovation capabilities based on data relating to scientific, technological, and industrial capabilities. In the three datasets considered, the paper analyzes data at country and field level for the period 2000-2020. Years were grouped into 4-year periods as a measure to control output volatility, particularly for smaller countries and less prolific fields.

The focus on countries is to describe global trends, but it must be acknowledged that the design of innovation policies may require analysis at more disaggregated levels, such as regions, clusters, or cities. Moreover, the period studied is not large enough to understand all the stages of an innovation process, which in some cases can span many decades and require a more detailed assessment of how individual ideas are transformed into final products. However, it allows us to assess the current state of scientific, technological, and industrial capabilities, as well as to provide insights into their geographical distribution, degree of sophistication, recent evolution, and potential connections.

Scientific progress, the bedrock of human knowledge, is reflected in international scientific publications. These articles have been published in internationally recognized academic journals. Our paper uses the data for scientific articles compiled in the Web of Science, Science Citation Index Expanded collection, which are grouped into 169 distinct scientific subjects serving as scientific fields. These fields are grouped into 11 scientific domains. Countries are assigned scientific publications based on the university affiliation address. Fields in social sciences and humanities were excluded in the analysis. See annex for detailed summary of all scientific fields considered in the analysis.

Technological advancement is encapsulated in international patent family data sourced from the European Patent Office's (EPO) Worldwide Patent Statistical Database (PATSTAT, October 2023), the United States Patent and Trademark Office (USPTO) and WIPO's Patent Cooperation Treaty (PCT) collections. Our main unit of analysis is the first filing for a set of patent applications filed in one or more countries and claiming the same invention. Each set containing one first and, potentially, several subsequent filings is defined as a patent family. Our analysis focuses only on foreign-oriented patent families, also known as international patent families. Foreign-oriented patent families concern those inventions for which the applicant has sought for patent protection beyond its home patent office. This definition includes patent applications by applicants filing only abroad, filing only through the PCT system or any international system (such as ARIPO, EPO, OAPI, etc.). The international patent families are the opposite to domestic-only patent families, which refer to those patent applications filed only at the applicant's home office – regardless of how many filings in the home office there are within the same family – without any subsequent foreign filing through the Paris or PCT routes. Likewise, patent applications with applicants of more than one origin are foreign-oriented patent families.

The patent data is grouped into 172 technological fields based on the international patent classification (IPC) and the inventors' addresses provide the information to assign a country. These fields are grouped into 14 technological domains. See annex for detailed summary of all technological fields considered in the analysis.

Product innovation can find its expression in international manufactured exports. Products that are competing in the international market have assured a certain degree of competitiveness that can be related to an innovative product. We have used the UN COMTRADE database to trace the global journey of 274 distinct product fields for all countries and years. These fields are grouped into 15 productive domains. See annex for detailed summary of all productive fields considered in the analysis.

The 3 datasets are concatenated into one table with 5 columns.

- *Year*. A numeric variable with 4-year periods, indicated by the last year of each group. 5 unique values.
- *Country*. Categorical variable for 2-letter country codes. 154 unique values that can be grouped by income group[3] or region.
- *Field ID*. Categorical variable for fields. 626 unique values that can be grouped into 11 scientific domains, 14 technological domains and 15 productive domains.
- *Dimension*. Categorical variable for innovative dimensions. 3 unique values.
- *Count*. Number of innovative outputs. Productive outputs measured in USD.

The combination of all unique values results in a dataset of 482,020 observations. Table 1 shows a sample of such data.

Table 1. Innovation outputs data sample

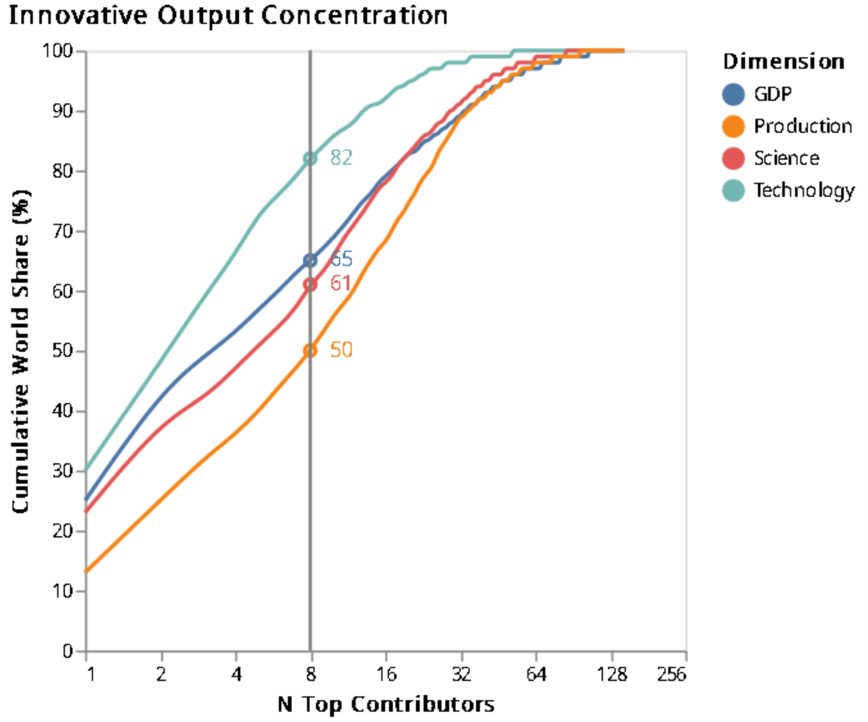
Year	Country	Field ID	Dimension	Count
2020	UY	T - B02-29	T	0.0
2016	SI	P - 773	P	6.5e+08
2020	BW	P - 285	P	6.2+02
2020	US	T - F27	T	7.5e+02
2004	SV	S - 506	S	0.0

Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

The innovative outcomes of all three dimensions are highly concentrated in a few countries. Over the past 4 years, the top eight countries (5 percent of the countries used in this analysis) account for 50 percent of exports, 61 percent of scientific publications and 82 percent of international patenting. Technological and scientific outcomes are significantly more concentrated than exports, the first being even more concentrated than GDP. As shown by the three indicators in the world's exports, scientific publications and international patent families remain concentrated in large countries today (Figure 1).

[3] We make use of the World Bank's income classification to refer to particular country groups. The classification is based on gross national income per capita in 2018 and establishes the following four groups: low-income economies (USD 1,135 or less); lower middle-income economies (USD 1,136 to USD 4,465); upper middle-income economies (USD 4,466 to USD 13,845); and high-income economies (USD 13,846 or more). More information on this classification is available at http://data.worldbank.org/about/country-classifications.

Figure 1. Innovative outputs are highly concentrated for all dimensions.



Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

A few economies – namely China, France, Germany, Japan, the Republic of Korea, and the United States – are among the top countries in all three indicators for the last four years of available data. Not surprisingly, as Table 2 shows, most of the innovation outcomes are concentrated in high-income economies. The size of the economies also matters, as China and, to some extent, India are notable exceptions to the high-income economies' concentration thanks to their large size.

Table 2. Top 8 contributors per dimension, 2016-2020.

Rank	Production	%	Science	%	Technologies	%	GDP	%
1	China	12.6	China	22.9	United States	29.9	United States	25.0
2	United States	12.0	United States	14.8	Japan	18.3	China	18.4
3	Germany	7.4	United Kingdom	4.8	China	11.1	Japan	5.5
4	Netherlands	4.1	Germany	4.6	Rep. of Korea	7.0	Germany	4.4
5	France	4.1	India	3.7	Germany	6.7	United Kingdom	3.5
6	Japan	3.9	Japan	3.5	United Kingdom	3.4	France	3.1
7	Singapore	3.2	Rep. of Korea	3.2	Canada	2.8	India	3.1
8	Italy	3.2	France	3.1	France	2.7	Italy	2.2

Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE, World Bank WDI.

3.2 Measuring relative innovation capabilities

In such a skewed and concentrated landscape, most innovative fields have the same countries as their top contributors. For instance, Germany, United States, Japan, and Korea, combined, contribute to 45% of all productive outputs in the motor car field. These countries host the headquarters of most of the world's leading producers in the field, such as Volkswagen, General Motors, Honda, and Hyundai. These countries shape and direct much of the innovation in their respective fields (WIPO, 2022b). Therefore, it is hard to argue that these economies do not master such innovation capabilities.

However, many economies hardly appear in the picture. Non-large and non-high-income countries have limited absolute resources to allocate into producing outcomes in every field. Often, these countries observe an above average share of outcomes in a small set of them. These countries need to prioritize the distribution of resources to build capabilities where their economy may have a natural or historical advantage. These choices may also be the result of long-planned industrial policies that may have been aimed at leveraging existing economic advantages from nature or history or completely changing capabilities.

Following the economic complexity literature (Hidalgo and Hausmann, 2009; Hidalgo *et al*, 2007), our method starts by tackling how to measure innovation capabilities in relative terms. Relative capabilities embody the pro-active or market-led choices that ecosystems make when allocating resources. If a country performs better in a determined field relative to other countries, this comparative advantage provides evidence on the capability of the economy to produce innovative outputs in the field. But what does it mean to have a comparative advantage?

Following Balassa (1965), our methodology uses the output of each dimension to compute country capabilities for each period by calculating the Revealed Comparative Advantage (RCA) indicator as:

$$RCA_{c,p,f} = \frac{Y_{c,p,f} \Big/ \sum_{f}^{F} Y_{c,p,f}}{\sum_{c}^{C} Y_{c.p,f} \Big/ \sum_{f}^{F} \sum_{c}^{C} Y_{c.p,f}} \qquad (1)$$

Where $Y_{c,p,f}$ *is the total output for country* c *in period* p *for field* f*,* C *is the set of countries.* P is the set of periods, and F is the set of fields.

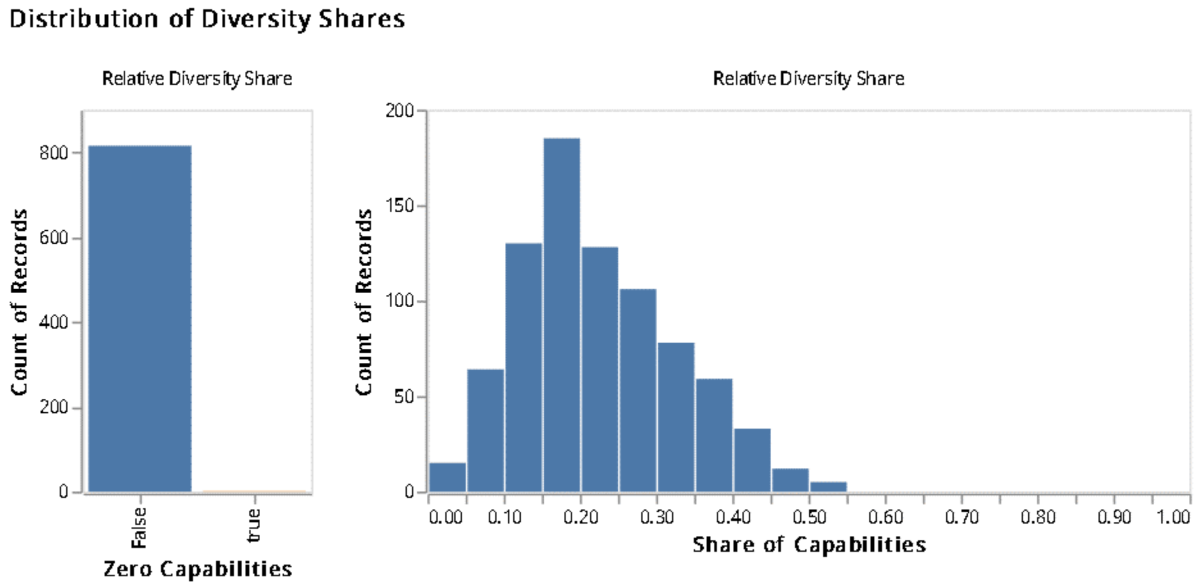
This continuous indicator is the ratio between a country's share of outputs in a field versus the world share in the same field. Typically, a RCA_{cpf} score above unity is consider as flag of relative specialization.[4] In other terms, a country c having an RCA_{cpf} above unity implies that it has the innovation capabilities to produce output in the field f at period p. Formally:

$$Capability^{rel}_{c,f,p} = \begin{cases} 1 & if \quad RCA_{c,p,f} > 1 \\ 0 & if \quad RCA_{c,p,f} \leq 1 \end{cases} \qquad (2)$$

Relative capabilities, by definition, assign at least one capability to each country. This can be seen in Figure 2 (left), where all countries have at least one capability. This is a relevant trait of the approach as we can always assess which capabilities are given priority for any given country at any period. As a result, the distribution of the share of capabilities that countries have is not very concentrated (Figure 2 right). Countries specialize on average around 20% of all capabilities, and always less than 60% of capabilities.

[4] It is possible to use other RCA thresholds, such as 5% (RCA>1.05) or 10% (RCA>1.1) above the world's average.

Figure 2. Relative capabilities distribution



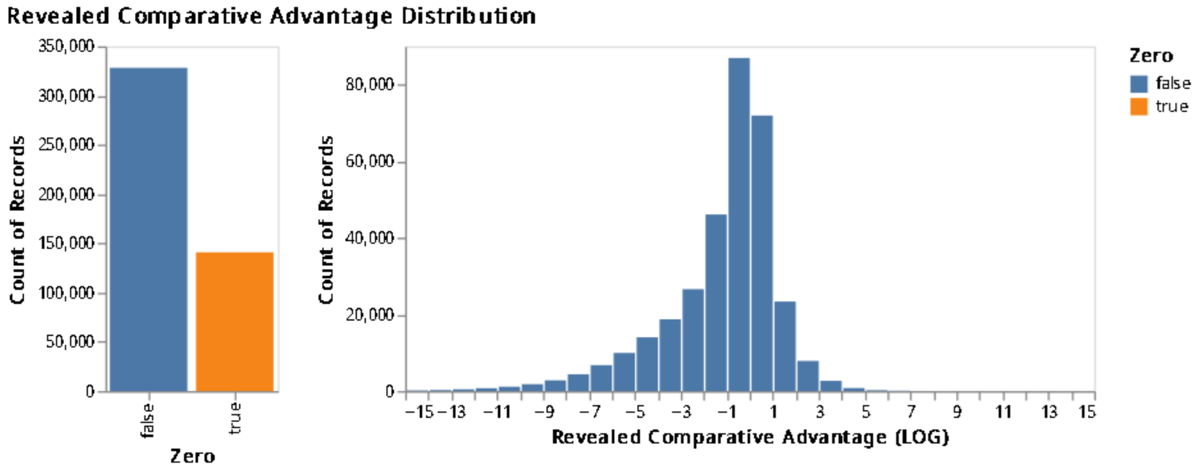
Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

It is important to note that large and diversified economies can be penalized by this approach. By the above definition of RCA_{cpf}, every country for every period will always have at least one field above 1, but also at least another field below 1. This implies a zero-sum situation, where no country can ever achieve a complete diversification (or complete lack of it). Similarly, the larger a country is, the more it contributes to the world's average. This means that the variability of its shares above and below the world's thresholds is artificially smaller. Such lower variability around the threshold makes the decision range between attributing or not a given specialization very narrow. Figure 3 shows the distribution of the RCA indicator for all countries, fields and periods.

Hence, innovative countries with a high absolute number of outputs in a field may not be attributed this capability just because it is not relatively specialized on it. This could result in highly unintuitive cases where the main contributor of a given field does not have a capability just because it is relatively better at doing other things.

On the other hand, less active ecosystems with low numbers of outputs in a specific field, may still be granted a capability despite having a significantly smaller contribution to the field. Less active ecosystems with tenuous technological and scientific subsystems will often report just a handful of scientific articles or patents per period, if any. In such cases, the RCA indicator fluctuates between extreme values on both sides of the distribution. Therefore, each year they will experience a high variance on their capabilities, affecting their relative specialization scores greatly.

Figure 3. Distribution of RCA, 2001-2020.



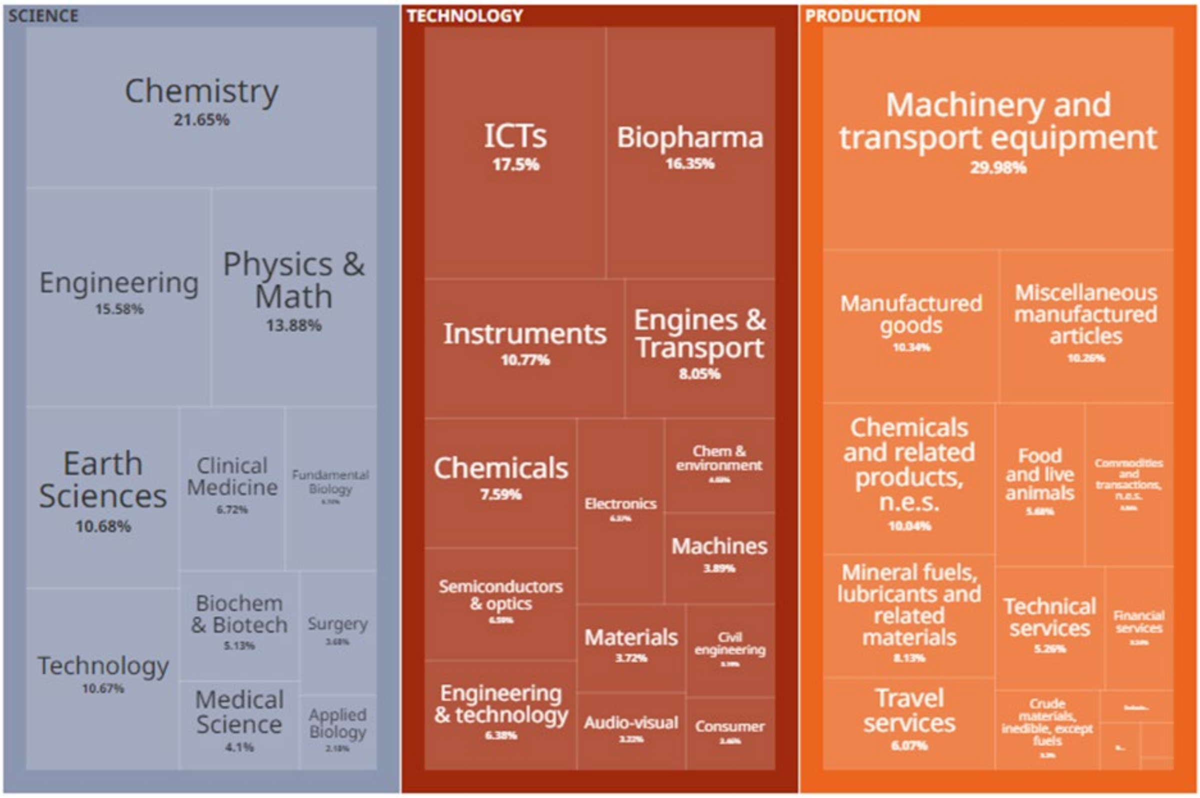
Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

3.3 Measuring absolute innovation capabilities

An alternative to the above-mentioned issues is to focus on the absolute innovation capabilities. The concept of absolute capability embodies the basic idea that being a successful and leading contributor in a given field directly implies having enough related know-how. As mentioned above, when countries concentrate the lion's share of the scientific, technological and production output of certain fields, it is hard to argue that these economies do not master the related innovation capabilities.

What does it mean to be a leader? In other terms, where to put a threshold to attribute an absolute innovation capability? Each field can have different distributions and levels of output. In fact, much alike how some countries concentrate most innovative outputs, the share of global activity by domain is far from even. Figure 4 shows how, roughly speaking, 3 out of 11 scientific domains, 4 out of 14 technological domains, and 3 out of 15 productive domains hold half of all activities. Similar patterns apply within many domains. In ICT technologies, for example, 2 out 10 fields represent 75% of all the domain activities.

Figure 4. Domain distribution of innovative outputs, 2016-2020.



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

The skewness found in this data means that in order to assign absolute capabilities, the methodology must incorporate the distribution of each field. The Herfindahl–Hirschman Index (HHI) applied to each of the 626 fields in the analysis provides a measure of the level of concentration for each field, in each period.[5] The inverse of this indicator (i.e. $1/HHI_{fp}$) provides a measure of the "effective" number of equally-sized countries contributing output to an specific field at every period.

Figure 5**Error! Reference source not found.** illustrates the average "effective" number of countries for each domain in the period 2017-2020. Virtually all domains score less than 15 "effective" countries, indicating a high concentration. Technological domains – and fields within these – show the highest concentration, as they are usually represented by less than 10 "effective" countries.

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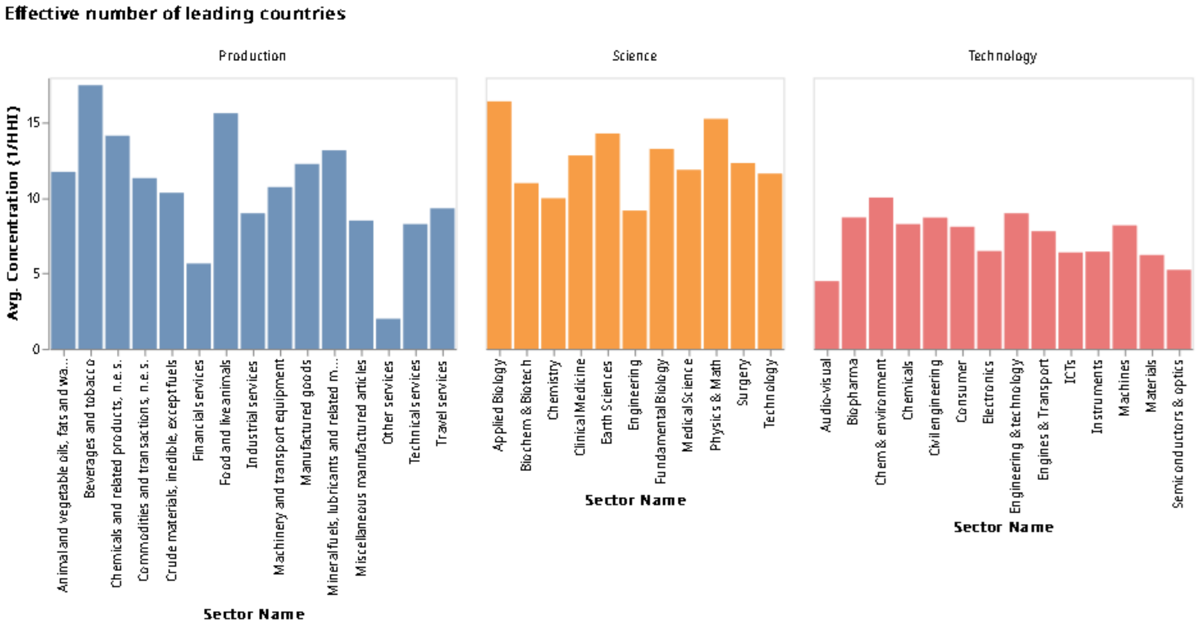
[5] The Herfindhal-Hirschman Index is computed as $HHI_{fp} = \sum_c^C s_{fpc}^2]$, where s_{fpc} is country c's share of outputs field f in period p.

Figure 5. Average "effective" number of countries leading per domain, 2017-2020.

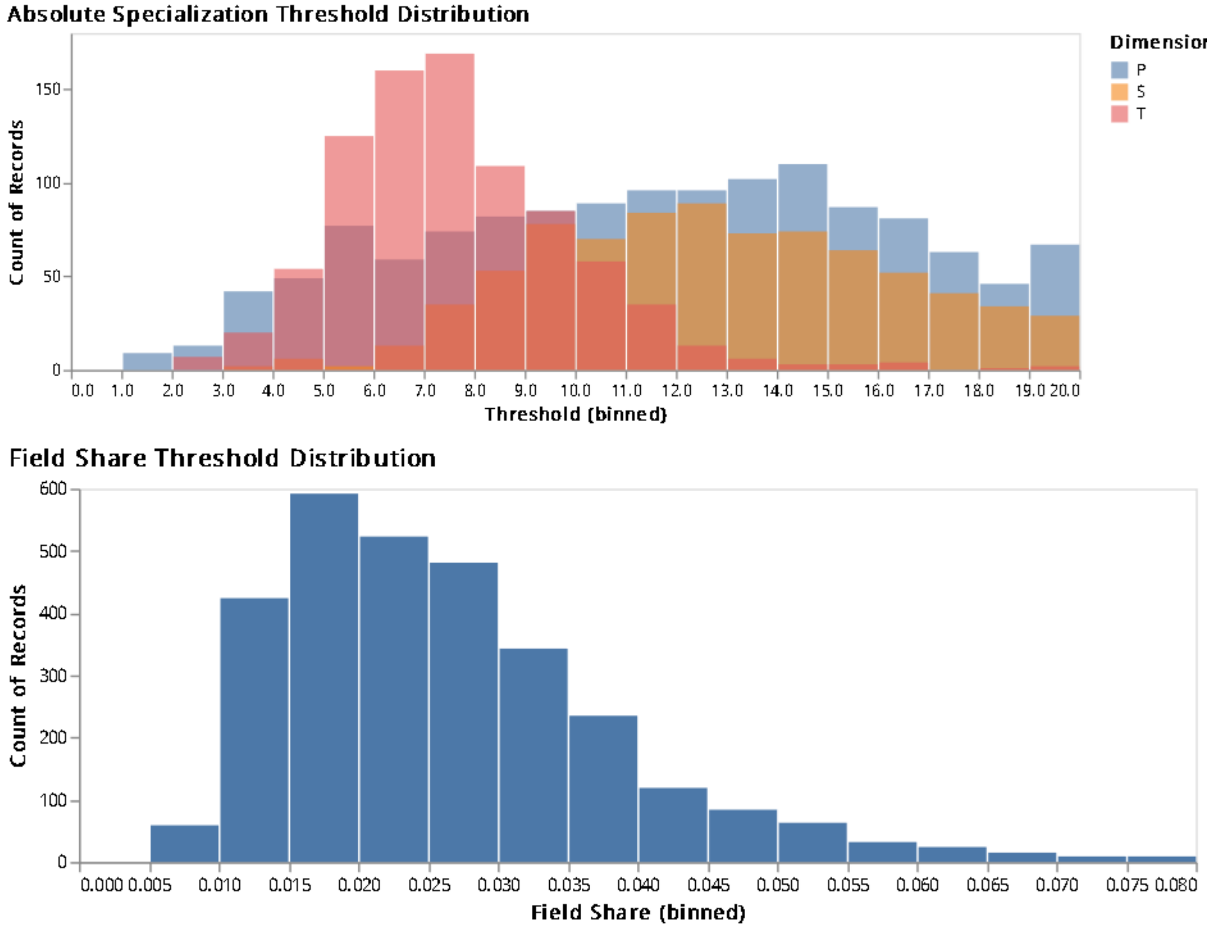


Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

We argue that the number of effective countries per field can serve as a threshold to grant absolute capabilities. The rationale is that any country whose contribution to a field ranks within the respective threshold can be reasonably assumed to have enough innovation capabilities to produce output in that field.

Figure 6 (top) shows the distribution by dimension of all field and periods thresholds (i.e. HHI_{fp}^{-1}). It is worth noting that while 8 "effective" countries seem to be the most common threshold, it is mainly due to the technological dimension. Both science and production allow for more countries to get these capabilities. Figure 6 (bottom) indicates the share associated with each threshold. In essence, countries begin to get absolute specializations once they surpass the 1% contribution of a field.

Figure 6. Threshold distribution for absolute capabilities, 2000-2020.



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

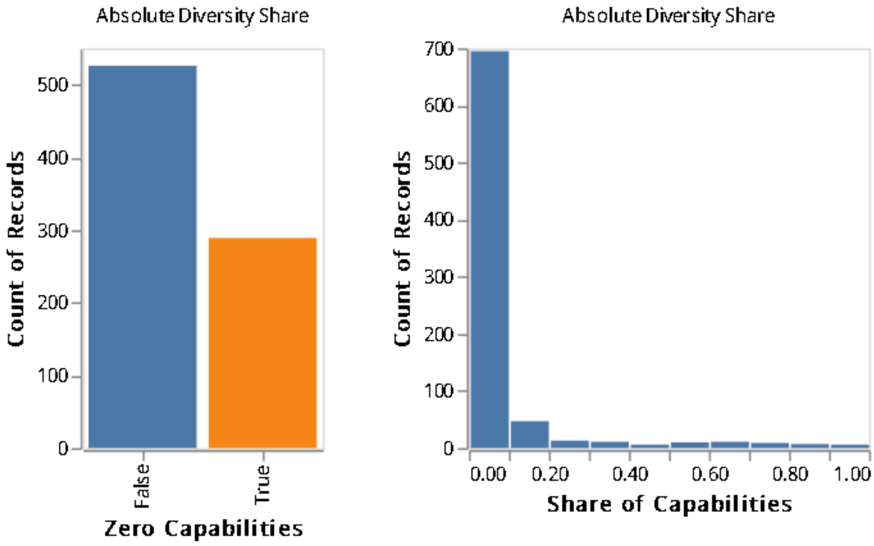
We argue that the number of effective countries per field can serve as a threshold to grant absolute capabilities. Any country whose contribution to a field ranks within the respective threshold of the period, is capable to produce the innovative output. Formally:

$$Capability_{c,f,p}^{abs} = \begin{cases} 1 & if\ HHI_{f,p}^{-1} \geq Rank_{c,f,p} \\ 0 & if\ HHI_{f,p}^{-1} < Rank_{c,f,p} \end{cases} \qquad (3)$$

Figure 7 shows the outcome of assigning capabilities exclusively on absolute terms for all periods. Applying this approach results in many countries without any innovative capabilities and most countries having only a handful of capabilities. Indeed, Figure 7 (left) shows that on average 35% of countries (289 country-periods) do not have any absolute capabilities. While Figure 7 (right) shows that, using the same approach, most countries have less than 10% capabilities at any period.

As a result, assigning capabilities based on absolute specialization not only penalizes economies with less efficient innovation ecosystems, but also those smaller economies with less overall resources to distribute across different innovation fields. For instance, Bahrain, and Cyprus are examples of developed economies with functioning innovation ecosystems that do not gather any absolute innovation capability.

Figure 7. Absolute capability distribution, 2000-2020.



These results reflect the level of concentration that is seen for innovative outputs worldwide. By penalizing innovation ecosystems based on scale, some relevant capabilities may be filtered out, particularly those that involve active efforts made by countries with less resources.

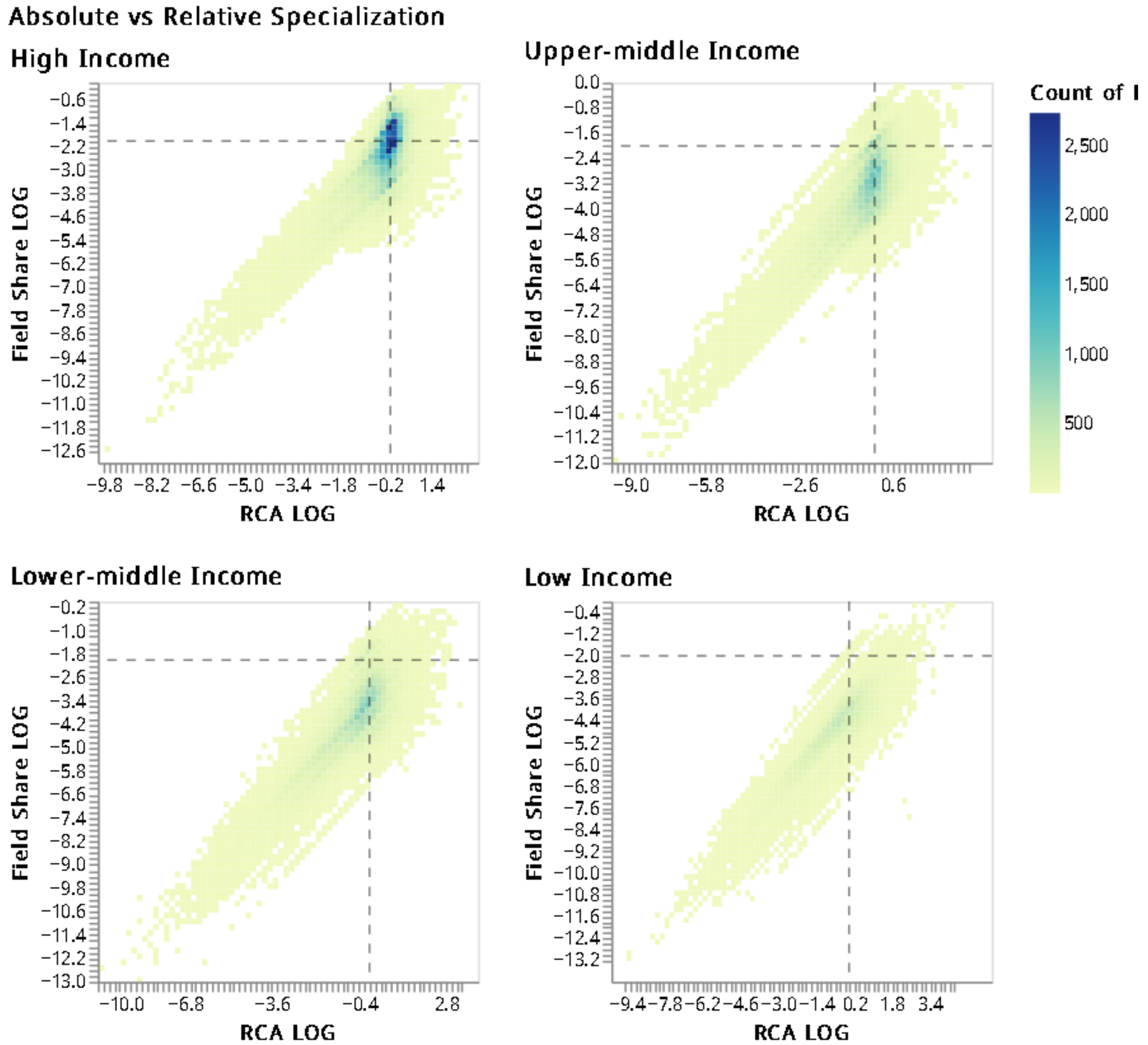
3.4 Innovative capabilities

To conclude the section, we argue that both approaches are equally important when measuring innovation capabilities at global scale. On one side, there are those capabilities that can be granted based on absolute terms if a country's contribution is high enough. On the other, the choices that smaller countries make on where to allocate their limited resources can make them attain relative capabilities.

Our suggested method to consolidate these tackles how to measure both types of capabilities in a binary fashion. Countries either have or do not have the capability – absolute or relative – to innovate in a given field and period. This simplification allows to compare between innovation ecosystems within the framework of complexity, relatedness, and smart specialization strategies.

Figure 8 displays the distribution of the indicators used for both methods at the same time, divided by income group. The vertical lines display the RCA thresholds while the horizontal line is the 1% share of the field. The tradeoff between the different economies is visible. High income economies tend to have most of their capabilities around both thresholds, with a high amount of them being both relative and absolute. The rest of the groups show some accumulation around the RCA threshold, but with significantly lower shares and very few observations on the upper-right quadrant.

Figure 8. Absolute and relative capability specialization by income groups



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

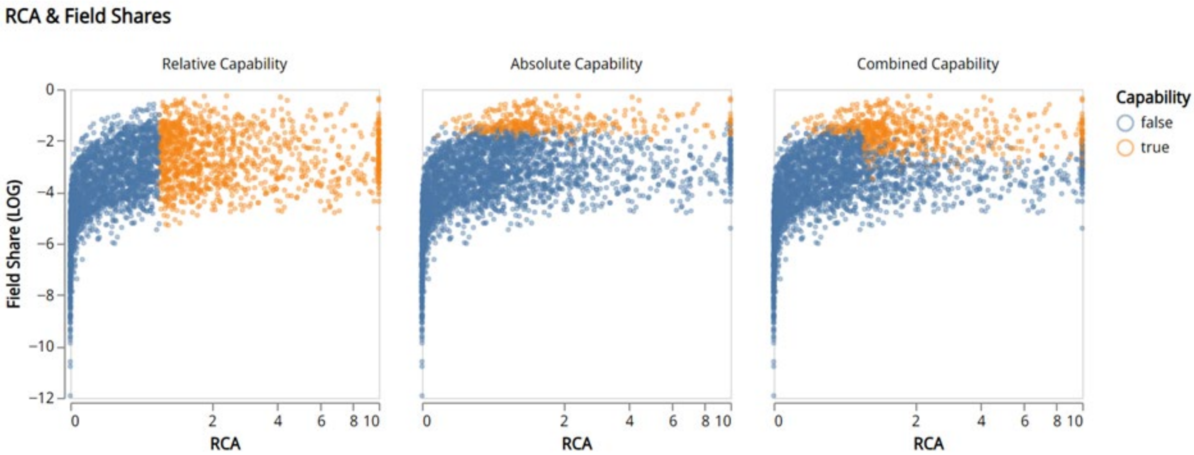
We propose a combination of relative and absolute capabilities to capture innovation capabilities in skewed scenarios. First, the method considers all absolute capabilities as innovation capabilities. Second, it only adds the relative capabilities for countries whose absolute contribution meets a second threshold, measured by 3 times the number of effective countries of the field.

Formally:

$$Capability^{inno}_{c,f,p} = \begin{cases} 1 & if\ RCA_{c,p,f} \geq 1\ or\ HHI^{-1}_{p,f} \geq Rank_{c,p,f} \geq 3 * HHI^{-1}_{p,f} \\ 0 & if\ RCA_{c,p,f} < 1\ or\ 3 * HHI^{-1}_{p,f} \leq Rank_{c,p,f} \end{cases} \quad (4)$$

The limit imposed by the second threshold assures that now smaller economies need to attain a degree of critical mass to have a capability that can be compared with the ones that larger economies hold. Figure 9 shows the same sample of 5000 observations mapped in the RCA and Field Share space and highlights the capability assignment of the three different methods. The combined method that this paper proposes is somewhat between the first and second options.

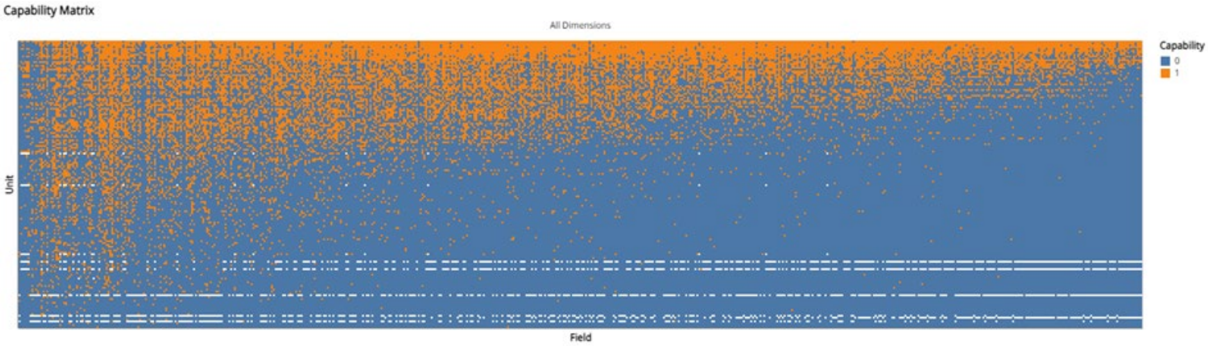
Figure 9. Relative, absolute and combined capabilities



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data. Based on a random sample of 5000 capability-country-period observations. Y-axis expressed in logs.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

The full set of capabilities can be displayed using the capability matrix for a given period, seen in Figure 10 for the period 2017-2020. The matrix has 154 rows (one for each country) and 626 columns (one for each field), and its intersections are colored based on the existence of a capability for each country and field combination. These types of matrixes are used as an input to compute complexity indicators.

Figure 10. Capabilities matrix: countries x capabilities



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

The following section will proceed to differentiate and value all types of capabilities.

4 EVALUATING INNOVATION CAPABILITIES

Our previous discussion has shown that an economy's innovation capabilities are related in part to both its degree of development and size, and partly to the specialization choices that an innovation ecosystem makes to further improve its functioning. But what about the qualities of these capabilities?

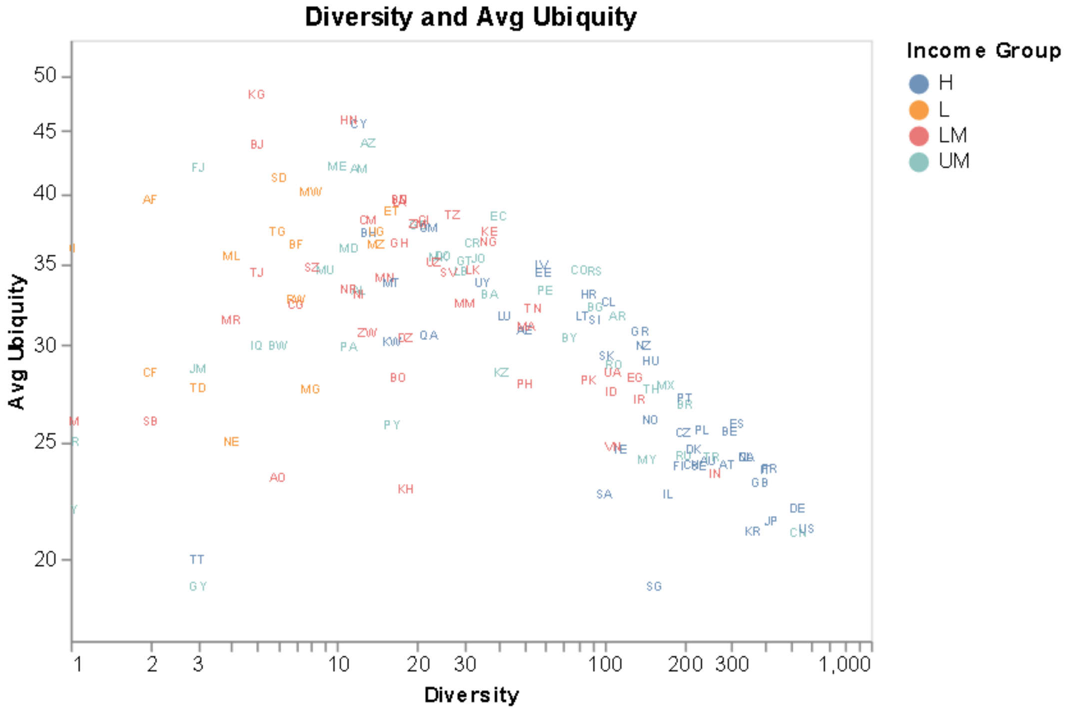
Assessing the worth of capabilities and their potential impact on a country's ability to innovate involves considering several factors. They include market demand, profitability, entry barriers, scalability, risk, and uncertainty. Of course, compiling detailed data measuring all these factors internationally is not easy.

The "complexity" concept used by economists solves this issue partially by asking "who does what?" and "what is done by how many?". A first step is to assume that ubiquitous capabilities are easy to adopt, and that rare ones are harder. However, this is not always the case. Some capabilities can be rare just because the incentives to develop them are low. Likewise, there may be widespread capabilities whose rewards are so high that countries are motivated to develop them, even at a high cost.

Hence, a second step is to look at how diversified are those countries that have these capabilities. As mentioned above, a broad set of capabilities allows innovation ecosystems to create increasingly sophisticated outputs. Therefore, if a rare technology appears exclusively in diversified countries, then it is the result of this process; and for it to be developed, it must be leveraged with other capabilities. Conversely, if this same technology were to appear in non-diverse countries, it would mean that countries do not need extra know-how in order to develop it, making the process it simpler.

Combining the diversity of countries and the rarity of their capabilities is formalized as the complexity concept. Computing the complexity indicator involves an iterative process considering (a) how each country specializes in each capability and (b) the number of countries specializing in each capability. In other words, complex capabilities are those that are rare and only diversified innovation ecosystems are able to make use of them. Conversely, complex innovation ecosystems are those that specialize in capabilities that are rare and in which only other diversified innovation ecosystems are specialized.

Figure 11. Countries' diversity and average ubiquity

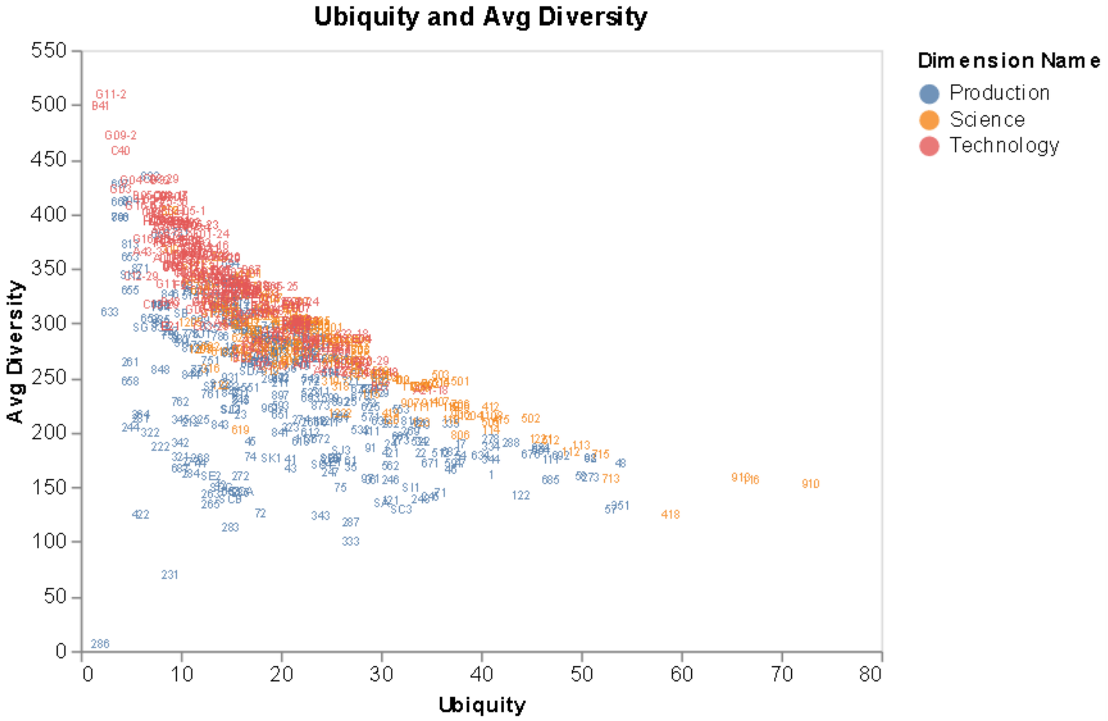


Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data. Axes expressed in logs.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Figure 11 illustrates the first step in computing the complexity indicator for all 626 innovation capabilities. This establishes a reciprocal relationship between the capabilities mastered by a country and the number of countries that master a capability. The countries panel plots the inverse relationship between how many capabilities a country is specialized in (diversity) against the average number of countries also specializing in this same set of capabilities (ubiquity). There is a clear downward trend shown.

As countries become more diversified in general their capabilities become less common across other countries. For instance, Afghanistan is specialized in just two capabilities – fruit and nuts, and spices – which are very common, with on average about a quarter of countries specializing in them. Conversely, Germany specializes in more than 500 capabilities, and on average less than an eighth of other countries specialize in any one of them. Not surprisingly, virtually all high-income economies are to be found at the bottom right of the figure displaying both more diverse and rarer capacities.

Figure 12. Capabilities' ubiquity and average diversity



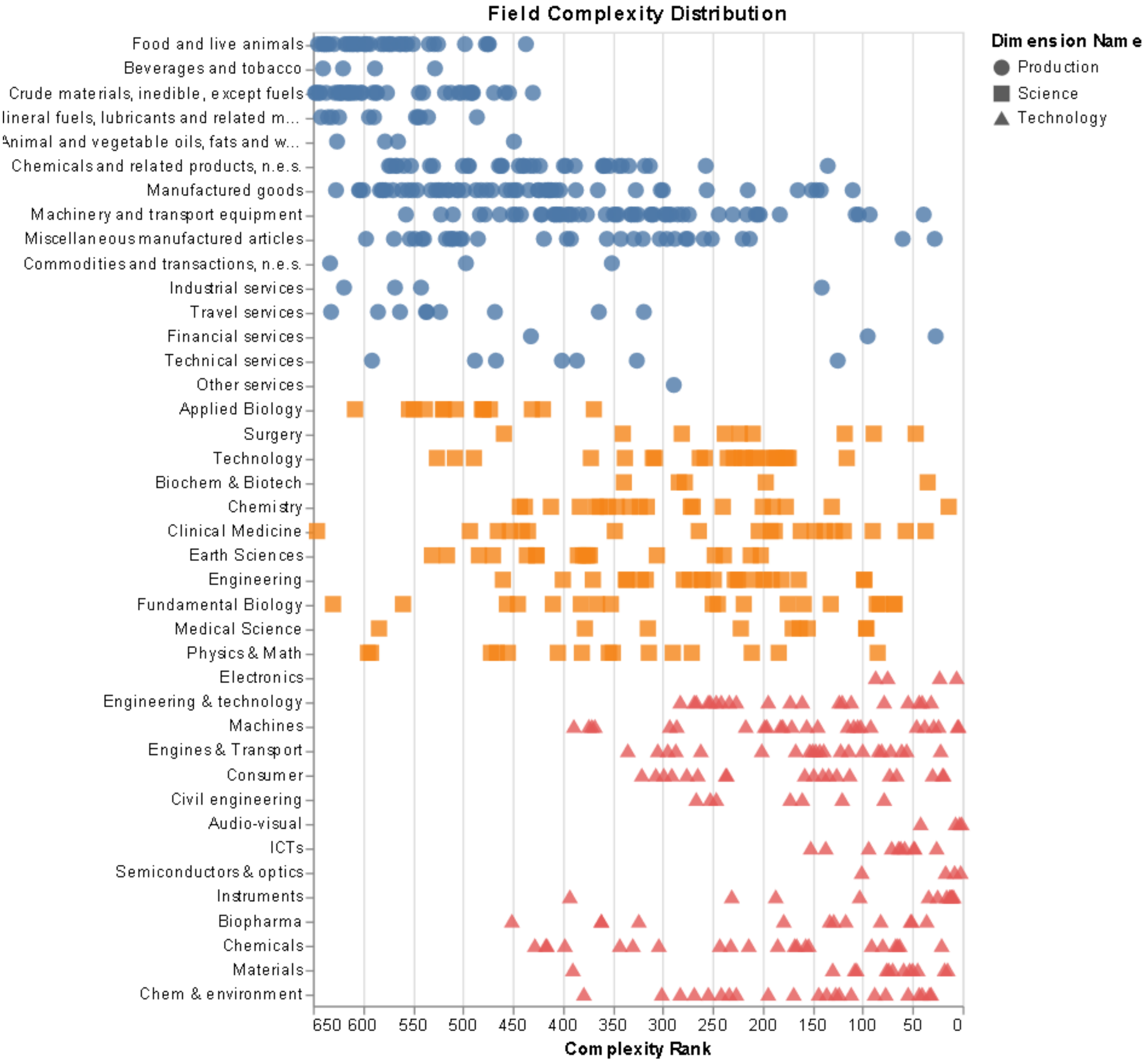
Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Figure 12 plots the same relationship from the perspective of capabilities: how many countries specialize in each capability against the average number of specialized capabilities in those countries. This panel also shows an inverse relationship between the commonness of a given capability (ubiquity) and how diversified those countries that specialize in the same capability are. For instance, 59 countries (38 percent of the world) specialize in the scientific capability tropical medicine but these same countries on average specialize in under a quarter of innovation fields. Conversely, a handful of countries specialize in the technological capabilities of audiovisual information storage and printing machines but on average these same countries specialize in 80 percent of all the capabilities.

4.1 The complexity of innovation capabilities

The iterative process following the principles of diversity and ubiquity produces a complexity indicator that measures the level of know- how required to master capabilities of different domains. Complex capabilities are those that everybody wants but few know how to develop. Figure 13 ranks innovation capabilities according to their capability complexity level for the period 2017-2020.

Figure 13. Field complexity rank by main domains



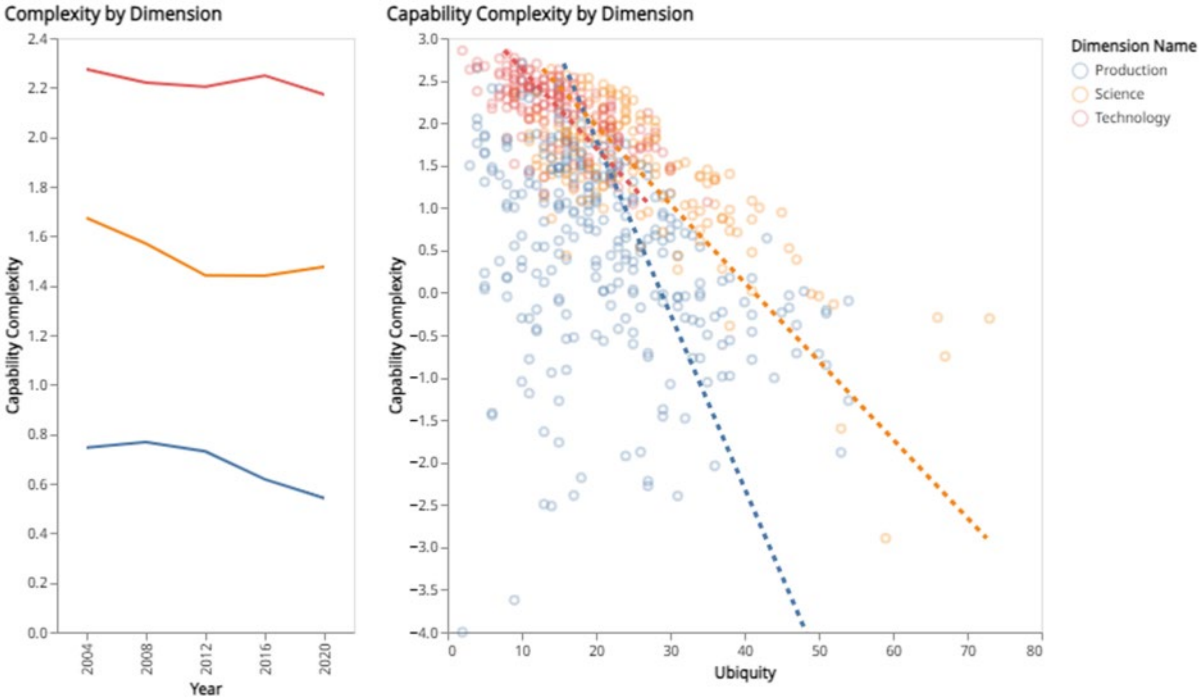
Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data. X-axis expressed as rank.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Our proposed methodology does not discriminate a priori between dimension subsystems. However, when we do group them *ex-post*, we find that there are consistent differences between these dimensions that can be identified by only looking at their ubiquity, average diversity, and product complexity.[6]

[6] We test this intuition by implementing a Decision Tree Classifier (DTC) that uses exclusively the ubiquity, average diversity, and product complexity to guess the to which dimension the observation belongs. The DTC algorithm can consistently predict correctly around 63% of observations using only 20% of the sample as train data. This performance is significantly higher than chance (33%).

Technological capabilities score, on average, the highest complexity. As described above, patenting activities are the most concentrated, hence, it is not surprising that they are classified as the most complex by the algorithm. Figure 14 displays, on the left, the average complexity of each dimension over time. Technological capabilities lead in complexity for the whole period, while scientific and productive ones follow subsequently, these being much closer to each other than the first one.

Figure 14: Field Complexity across Dimensions.



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Nonetheless, when looking at the overall distribution of the complexity of the 626 fields, there are capabilities within the runner-up dimensions that overlap with the technological dimension. Figure 14 (right) maps the average complexity and ubiquity for each of the 626 fields colored by dimension. As shown by the trend lines for each dimension, there is a consistent inverse relation between complexity and ubiquity.

The technology (red) and science (orange) trend lines share a very similar slope, while the product trendline – for both goods and services in blue – has a much steeper slope. This means that for the same level of complexity product fields are more likely to be produced by less countries – i.e., observe a much lower ubiquity. This is manifest for low complexity fields (bottom half of the chart), for which there is a visible difference between the ubiquities of products and scientific publications. For a low-end scientific field to be on the same level of complexity of a product, this field is still present in around twice the number of countries.

In addition, the dispersion of technological and scientific fields around the trendline is quite narrow, indicating that differences in ubiquity are highly indicative of their level of complexity. Production, on the other hand, shows a much greater variability, showing multiple fields with different levels of complexity at the same level of ubiquity. This also means that production capabilities are more often present in low complexity countries.

Table 3 shows these patterns more clearly by computing the R-squared for the trend lines for each dimension over the five period. Unsurprisingly from the above discussion, the regressions of complexity on ubiquity for the production fields have the lowest R-squared, ranging from .05 to .13. Interestingly, the same regressions for the scientific fields have the highest R-squared, ranging from .56 to .80. However, the estimated R-squared decrease quite consistently during the last two decades, which is likely due to the increase participation in scientific publication by less industrialized economies (WIPO, 2019; Miguelez *et al.*, 2019). Last, the regressions of complexity on ubiquity for the technological fields show relatively high and stable R-squared measures, ranging from .41 to .46.

Table 3. R^2 of regressing Complexity over Ubiquity by period and dimension

Period	**R^2**		
	Production	**Science**	**Technology**
2001-2004	0.13	0.80	0.41
2005-2008	0.05	0.74	0.40
2009-2012	0.13	0.76	0.46
2013-2016	0.09	0.66	0.41
2017-2020	0.09	0.56	0.43

Notes: Reported R2 derive from OLS regressions of Complexity on ubiquity with a constant.

Grouping these fields into their respective sectors serves to identify, at the larger scale, where we can find the most complex fields in each dimension. Table 4 ranks domains based on their dimension and complexity. It is interesting to note that some domains across dimensions that are likely related can have a similar ranking, indicating that their required know-how is on par. For instance, chemicals and biopharma technologies have a similar ranking to biochemical and biotechnological scientific outputs. In addition, most commodities, raw materials, and services are on the lowest third of the ranking, indicating that these are the capabilities that are most easily obtainable. In contrast, the sectors that are consistently requiring high amount of know-how are associated with innovations that require more infrastructure, such as technological innovations of all sorts, machineries, and surgical publications.

Table 4. Complexity ranks by domains

Technological Sector	Rank	Production Sector	Rank	Scientific Sector	Rank
Audio-visual	1	Machinery and transport equipment	11	Surgery	13
Semiconductors & optics	2	Other services	18	Biochem & Biotech	16
Electronics	3	Chemicals and related products, n.e.s.	23	Medical Science	17
Instruments	4	Miscellaneous manufactured articles	24	Technology	19
Materials	5	Financial services	26	Fundamental Biology	20
ICTs	6	Manufactured goods	28	Clinical Medicine	21
Engines & Transport	7	Technical services	29	Engineering	22
Machines	8	Industrial services	31	Chemistry	25
Consumer	9	Travel services	32	Physics & Math	27
Chem & environment	10	Mineral fuels, lubricants and related materials	33	Earth Sciences	30
Chemicals	12	Commodities and transactions, n.e.s.	34	Applied Biology	36
Biopharma	14	Crude materials, inedible, except fuels	35		
Engineering & technology	15	Food and live animals	37		
		Beverages and tobacco	38		
		Animal and vegetable oils, fats and waxes	39		

Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

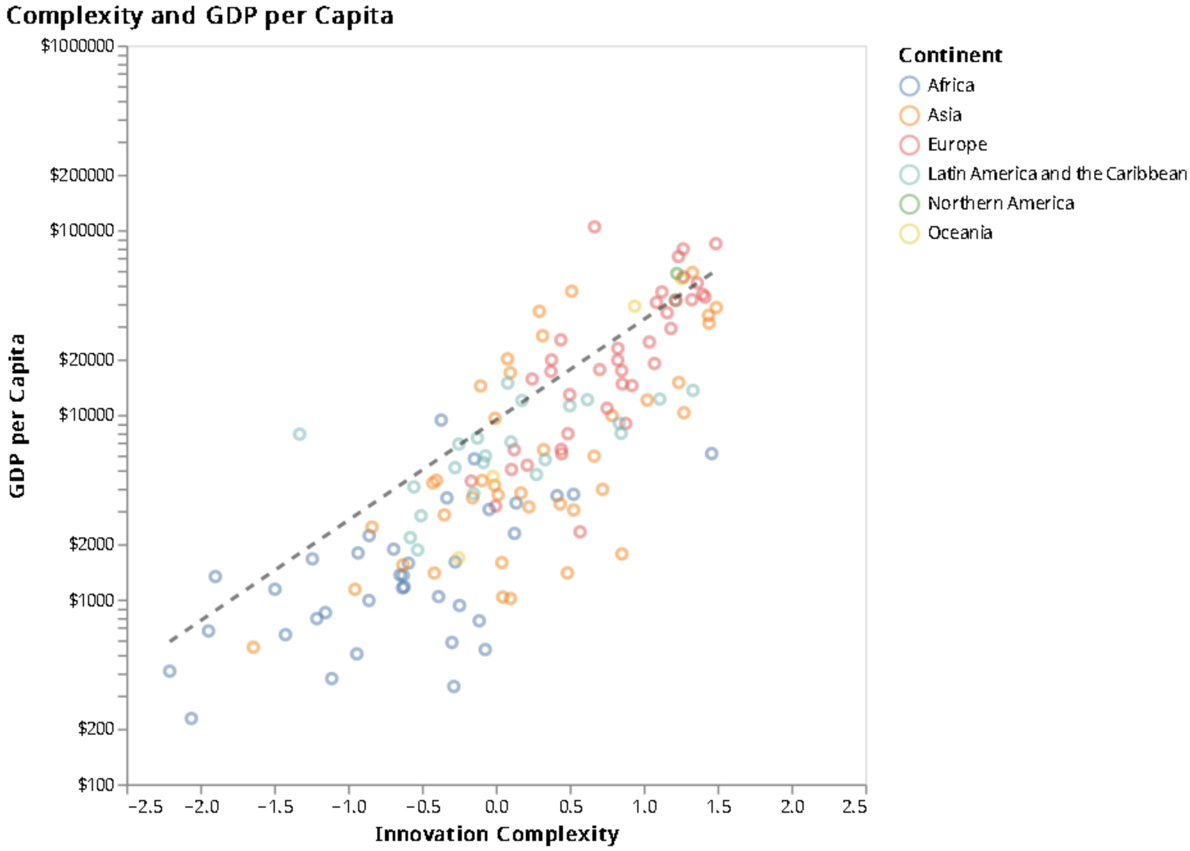
The ranking of the domain complexity implicates that there is a complexity ladder that starts with the product capabilities in raw materials and commodities; followed by the production of science alongside services and manufactures; and finalizing with the technological innovations at the frontier represented by patenting activity.

4.2 Innovation complexity

Every country can assess in which step of the ladder they are in by looking into the complexities of their current capabilities. Following the economic complexity methodology, our approach stipulates that countries innovation complexity levels change when they gain and lose innovation capabilities. The innovation complexity indicator is, in essence, the average complexity of an ecosystem's capabilities. The metric extends the well-known Economic Complexity Index by adding technologies and scientific outputs into the pool of capabilities.

Why understanding the innovation complexity matters? Similar to the results for economic complexity mentioned in section 2, Figure 15 shows how our innovation complexity indicator is positively correlated with income per capita. Countries from the Northern America (green) region, Europe (red), and Oceania (yellow) are among the top GDP per capita and complexity scores. Several countries from the Asian region (orange) are also on this top right group, although many other Asian economies observe lower scores in both indicators.

Figure 15. How innovation complexity correlates with GDP per capita?



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data. Y-axis expressed in logs.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

While causality is hard to establish, our results substantiate what the economic literature has found for economic and technological complexity (Hausmann *et al*, 2024; Mewes and Broekel, 2022; Hidalgo *et al*, 2022; Hidalgo, 2021; Balland and Rigby , 2017; Hidalgo and Hausmann, 2009). In our case, countries that master complex innovation capabilities are often also those benefitting from high economic rewards.

Table 5 shows the slope, constant and R-squared estimations of regressing the GDP per capita (in logs) over our innovation complexity indicator. The relation is quite strong as we find that the R-squared estimations without any other control variables range from .41 to .56. In all periods, the slope is found positive and significant, ranging from .85 to 1.17. The economic meaning of these slopes is quite significant as well. Countries increasing its innovation complexity by one unit are expected to have 104% increase of their GDP per capita. Of course, a one unit increase of innovation complexity is quite a leap and only a few economies in our sample managed to do such increase in the last 20 years. Namely, Ethiopia, Iraq, Lao People's Democratic Republic, Panama, and Trinidad and Tobago managed to increase in average 1.6 innovation complexity units from 2001 to 2020. While this is partially explained by that, in most cases, they had a very low complexity score in 2001-2004; these economies, with the only exception of Trinidad and Tobago, observed a substantial increase in GDP per capita in the same period (a 131% average increase including Trinidad and Tobago).

Table 5. Regressing GDP per capita over Complexity by period

Period	R^2	Constant	Slope
2001-2004	0.54	8.44	1.13***
2005-2008	0.56	8.48	1.17***
2009-2012	0.56	8.49	1.09***
2013-2016	0.41	8.57	0.85***
2017-2020	0.55	8.57	1.03***
2001-2020	**0.52**	**8.51**	**1.04*** **

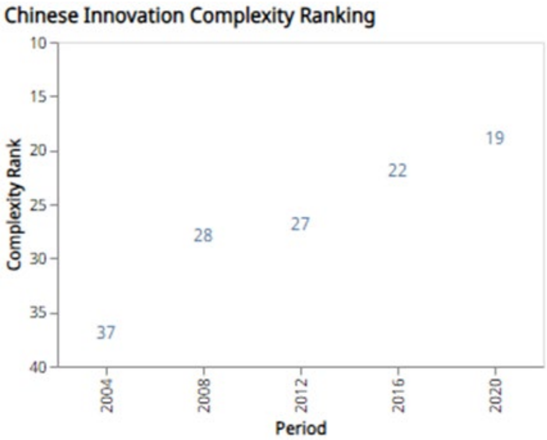
*Notes Reported regressors, R2 and p-values derive from OLS regressions on Ln(GDP per capita) over Complexity and constant. *** stands for p-values less than 1%.*

Such changes in innovation complexity occur across all countries although often in a less dramatic fashion. Overall, countries have increased their diversity and, to some extent, their innovation complexity during the past 20 years. This rise is mainly driven by countries in East and Southeast Asia and to a lesser extent those in southern Europe and South America. Other regions have experienced a reduction in diversity. North America, eastern and western Europe all saw a reduction in the number of capabilities during the same period. Yet, most the loss in diversity was in lower complexity capabilities. This partially explains why these countries maintain their high-income status. This trend may also partly explain why some Western countries – such as the United States and European Union (EU) countries – are adopting industrial and innovation policies designed to recover some of the capabilities they have lost and maintaining the complex ones they do not want to lose.

Several middle-income countries – such as the Republic of Korea, China and, more recently, India – have consistently applied policies aiming at increasing their level of overall know-how and, in many cases, at adding more complex know-how to their capabilities. As a result, the Republic of Korea has succeeded in becoming a high-income economy. More recently, India's continuous growth has put it on track to becoming an upper-middle income economy. Diversifying to more complex capabilities has helped, and continues to help, the economies in question move closer to the level of sophistication of the high-income economies.

While continuing to be an upper-middle income economy, China's impressive growth during the past two decades has left it on the verge of obtaining high-income status. China's innovation spurred economic growth is the typical example substantiating the strong relation between our innovation complexity and economic growth. China's new capabilities included technological know-how in ICT and transportation and scientific capabilities in medical science and clinical medicine. The addition of these complex capabilities means that China's is now 18 positions higher in the innovation complexity ranking than 20 years ago (see Figure 16). In the same period, China's GDP per capita has more than tripled, and a third of that increase can be explained by using the simple regression in Table 5.

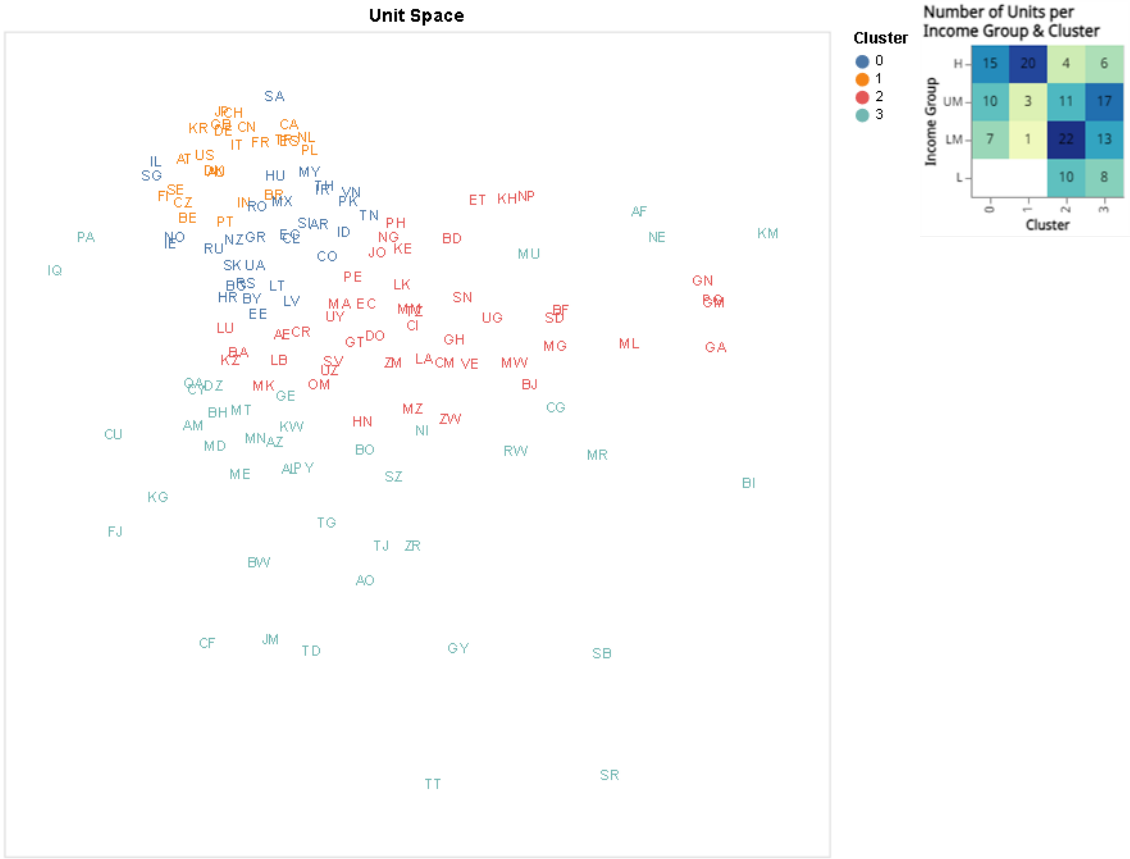
Figure 16. China's climbing the Innovation Complexity Ranking



Lower middle- and low-income countries alike are showing a decline in complexity levels, however. Rather than adding complexity, both groups have become "trapped" into focusing incrementally on less valuable capabilities thereby jeopardizing their ability to grow and exacerbating income inequalities around the world.

It is worth noting that high-income countries not only experience higher levels of complexity, but they also tend to share their sets of capabilities. Figure 17 (left) maps countries based on how similar they are in terms of their innovation capabilities without imposing any direct link to the overall basket of capabilities. Clustering them into four groups based on their position – mimicking the same amount of income groups – allows to highlight how most of the high-income countries are either on clusters 0 or 1. As shown in Figure 17 (right), cluster 1 includes a few of non-high-income economies. Clusters 2 and 3 are more heterogenous as are the only ones containing Low-income economies. Within these two, cluster 2 includes the highest number of lower-middle and low-income economies. Not surprisingly, these clusters also rank in average complexity according to their average income rank, where cluster 1 scores 1.18 of average innovation complexity, cluster 0 scores 0.69, cluster 3 scores -0.36, and cluster 2 scores -0.67.

Figure 17. Country innovation space



Note: 147 innovation ecosystems mapped using a spring layout (Fruchterman-Reingold force-directed algorithm) based on capability proximities, clustered into 4 groups using K-means method.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Additionally, these clusters observe different spatial concentration in Figure 17 (left). More spatial concentration indicates a more similar basket of innovation capabilities across all the countries within the same cluster, thus a more cohesive scientific, technological and production structure. Again, the spatial concentration of clusters shows a strong relation with the innovation complexity dispersion for countries in the same cluster. Cluster 1 is the most spatially concentrated group of economies and has the lowest dispersion of innovation complexity (a coefficient of variation of 15%), followed by clusters 0 (50%), 2 (-135%) and 3 (-234%).

These correlations, among other advantages explored by the literature, indicates that countries are encouraged to climb the complexity ladder, no matter the step they are in. However, the way that countries climb does not need to be linear. By understanding the interaction between fields both within a dimension and between dimensions, policymakers can find shortcuts that propel their countries closer to the frontier.

5 LEVERAGING INNOVATION CAPABILITIES

How can countries choose which capabilities to pursue? Over the years there have been several unsuccessful efforts made by policymakers to "recreate Silicon Valley" in their respective regions and states. The famous Californian hotspot was a small rural community at the beginning of the 20th century and is now recognized internationally as a major hub for technology and innovation, making it one of the places in the world with the most diverse and complex know-how. This success story resonates strongly in policymaking. However, other economies may be unable to replicate the multiple factors that made it possible.

Looking to develop high-complexity technologies where there are no solid foundations is like building a palace on an iceberg. Not only it will be hard to build but its inhospitable environment will make it hard to maintain and access. With no visitors nearby and nobody to fix it the structure will surely be abandoned and crumble at some point.

5.1 Innovation capability space and the principle of relatedness

Capabilities can be related by sharing common skills, knowledge, or resources, which means they often work well together and can be used together efficiently. Being proficient in one capability can often help countries develop or perform better in related capabilities, and vice versa. This intuition of the connection between fields can be formalized with the Proximity Indicator, where the proximity between fields is based on the co-occurrence of capabilities within a country. Proximity shows the connectedness between any pair of scientific, technological and production fields (i.e., capabilities). For any given pair of fields, proximity represents the probability that an average country will specialize in both fields at the same moment in time. It is based on the statistically significant co-occurrences of two capabilities in all countries.

$$\varphi_{f1,f2}=\frac{\left|\left\{c \mid M_{c,f1}=1 \text{ and } M_{c,f2}=1\right\}\right|}{\left|\left\{c \mid M_{c,f1}=1 \text{ or } M_{c,f2}=1\right\}\right|} \tag{5}$$

These pair-wise calculations form a network of innovation capabilities by connecting the 626 fields. We map this network in a two-dimensional space like the one in Figure 18, where the marker size reflects the field's share respective to the dimension total.

Figure 18. Innovation capability space

Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data. Domains labels positioned based on its fields average.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

In Figure 18, the more complex capabilities appear in the lower right corner. Most of the capabilities related to audiovisual, electronics and semiconductor technologies lie in that zone. In contrast, capabilities that require less accumulated know-how will appear more isolated, usually on the outskirts of the network on the upper left of the figure. This is the case for the production fields of many raw materials (iron and copper ores, cork, oils), food and live animals (cocoa, tea, rice), and some basic manufactured goods (such as those using tin or pearls and precious stones). Most of the intermediate complexity capabilities are at the center of the network.

Figure 19. Unit Spaces for selected countries and periods

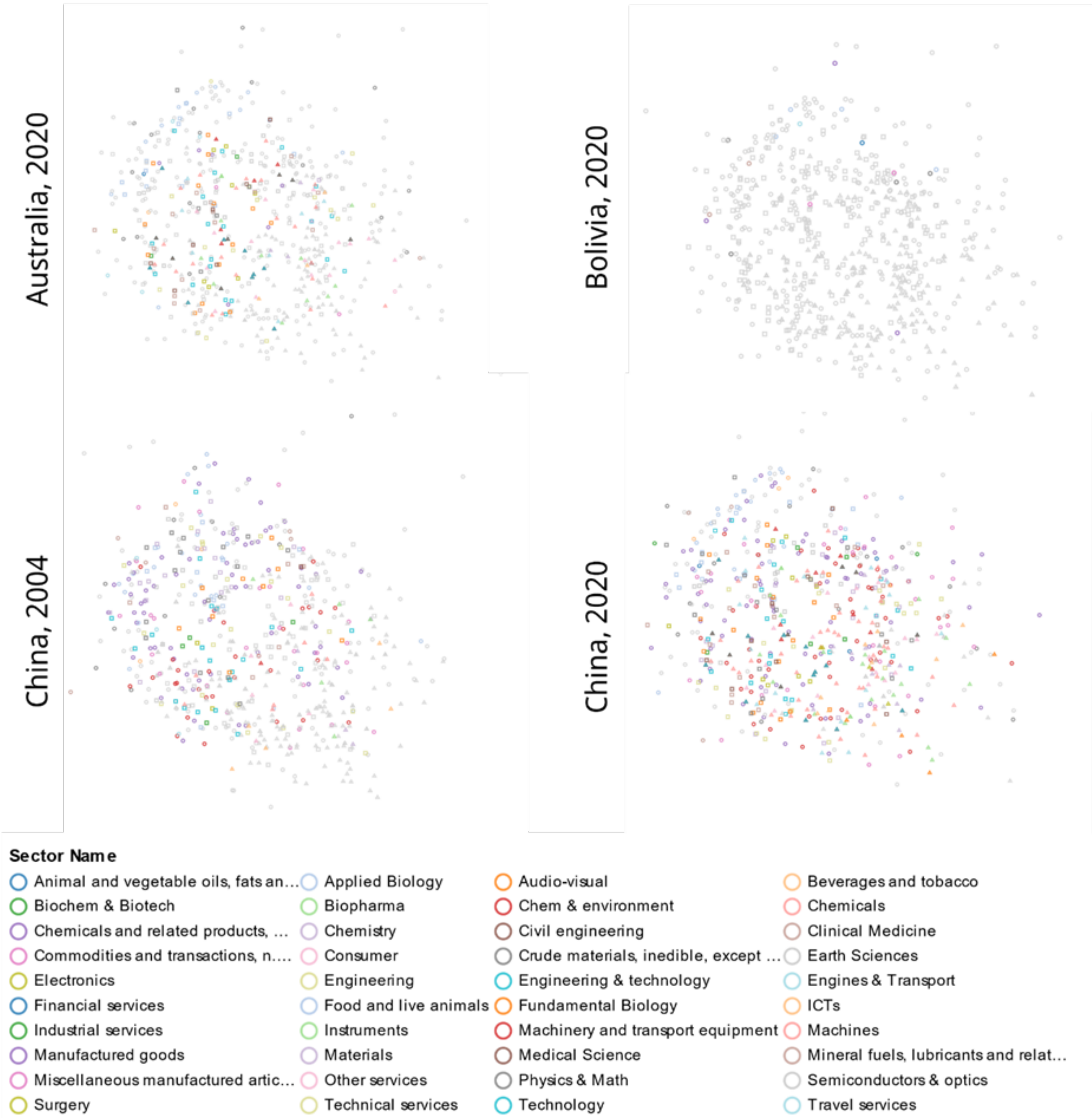


Figure 19 reproduces the capability spaces in Figure 18 for Australia in 2017-2020 (top left), the Plurinational State of Bolivia in 2017-2020 (top right) and China in in 2001-2004 (bottom left) and in 2017-2020 (bottom right). In all four, the non-grayed capabilities represent each country's current innovation capability specialization. Like any country with a more advanced level of innovation capabilities, Australia has innovation capabilities that are more centrally placed. In contrast, countries with a lower complexity – such as Bolivia – display a lower number of capabilities and these are located almost exclusively at the border of the network.

This comparison raises two important questions: (1) How is it that Australia reached its current level of innovation capabilities? (2) How can Bolivia catch-up?

As we discussed in the previous section, some countries have been consistently adding innovation capabilities during the past two decades and have benefited from an increase in complexity. But how targeted was the gain of new capabilities? Figure 19 bottom left and right show the change in China's capabilities over the past two decades. During this time China aimed and gained complex technological capabilities in the ICT domain, particularly in speech or audio coding or decoding, electronic circuitry, electric elements for telecommunications, and computing methods and technologies. More importantly, by 2020 China had gained most of the complex capabilities it was lacking in back the early 2000s. China's experience suggests that a country's current capabilities can indicate where to go next.

As an explanation, Hidalgo and Hausmann (2009) propose that economies tend to diversify incrementally, moving into activities that have similar skills to those they currently possess. They define this process as the "principle of relatedness" and suggest a metric. Their relatedness indicator captures the ease of obtaining the know-how needed to move into another product. It formalizes the intuitive idea that the ability of a country to produce a product can be revealed by looking at which other products it can produce.

$$RD_{cf} = \frac{\sum_{f'} M_{cf'} \cdot \varphi_{ff'}}{\sum_{f'} \varphi_{ff'})} \qquad (6)$$

Where $\varphi_{ff'} = proximity\ between\ activities\ f\ and\ f'$

Any structural transformation is a path-dependent process. However, there is room for agency. An additional interpretation of the indicator points to the risk of obtaining a new capability. When relatedness is high, the innovation ecosystem has know-how that is compatible with the target field, making the ease of diversification high. In contrast, when the ecosystem has low relatedness with their target field, the chances of succeeding are low.

Empirical studies have consistently shown that higher past economic or technological relatedness density predicts current specialization (Hidalgo *et al*, 2018; Hidalgo *et al*, 2007; Boschma *et al*, 2015). Following these studies, and similar to Hausmann *et al* (2024), we test the validity of the "principle of relatedness" in our innovation capability data in Table 6. We find a consistent positive and significant relation for both the past related density ($RD_{c,f,t-1}$) and the variation of related density ($RD_{c,f,t} - RD_{c,f,t-1}$) with observing the innovation capability in a given country (models 1-4 in Table 6). This suggest that having the related innovation capabilities (the "neighboring" capabilities in Figure 18) is a strong predictor of having a given innovation capability (models 1 and 2). It also means that a sudden increase in related capabilities ($RD_{c,f,t} - RD_{c,f,t-1}$) relates with having a given innovation capability (models 3 and 4).

Table 6 – Testing the Principle of Relatedness in innovation capability relatedness

	Capability (1)	(2)	(3)	(4)	**Entry** (5)	(6)	**Exit** (7)	(8)
$RD_{c,f,t}$	2.52 *** (0.03)	18.61 *** (0.28)	–	–	–	–	–	–
$RD_{c,f,t} - RD_{c,f,t-1}$	–	–	1.23*** (0.04)	18.61 *** (0.21)	1.58 *** (0.04)	2.05 *** (0.17)	-1.35 *** (0.04)	- 46.32*** (1.7)
Field Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Method	OLS	Logit	OLS	Logit	OLS	Logit	OLS	Logit
Observations	56474	56474	56474	56474	56474	56474	56474	56474
Global F test / chi-2	4789.7 ***	-38997.0***	4040.6 **	-38997.0***	141.5 ***	-39138.0	187.6 ***	-11423.0 ***

*Notes: *** = statistically significant at <1%; all estimations use robust variance and covariance estimator.*

The latter suggest a relation between having neighboring capabilities and the appearance of a new innovation capability. The above cited literature has consistently found that country managing to master the prerequisites of a capability are more likely to develop a new capability. Yet, the principle of relatedness is also found to works in the opposite direction (Boschma *et al*, 2015; Hidalgo *et al*, 2018). In other terms, even if a country manages to master the capability despite not having the prerequisites, it is probable that the new skill will not last long.

We model “entry” and “exit” more explicitly in models 5-8, by defining a dummy variables flagging when a country gains or loses an innovation capability. In models 5 and 6, we find a consistent positive and significant relation between the variation of related density ($RD_{c,f,t} - RD_{c,f,t-1}$) with developing new innovation capabilities. This means that a sudden increase in related capabilities predicts the “entry” into a given field. Reciprocally, in models 7 and 6, we find a consistent negative and significant relation between the variation of related density ($RD_{c,f,t} - RD_{c,f,t-1}$) with losing pre-gained innovation capabilities.

5.2 Mapping opportunities for innovation policy

Our results are consistent with the intuition that countries that are more related to certain innovation capabilities are more likely not only to enter this new field but also to maintain the related capabilities they already possess. Indeed, innovation ecosystems exit certain capabilities – especially complex ones – if they do not maintain the related capabilities already in their basket.

While suggesting that countries should gain and maintain complex innovation capabilities is easy, many countries are unable to attempt or succeed in the task. First, all countries face resources constrains limiting how many innovation policies they can attempt at the same time. Second, gaining an innovation capability is risky. Not every policy is successfully implemented, as many countries have tried before gain a given capability through industrial and innovation policies and failed. The two factors are not independent, as countries have even more limited resources when attempting to gain capabilities that are considered riskier. As resources become scarcer there is usually a prevalence of conservative investments where the probability of success is much higher.

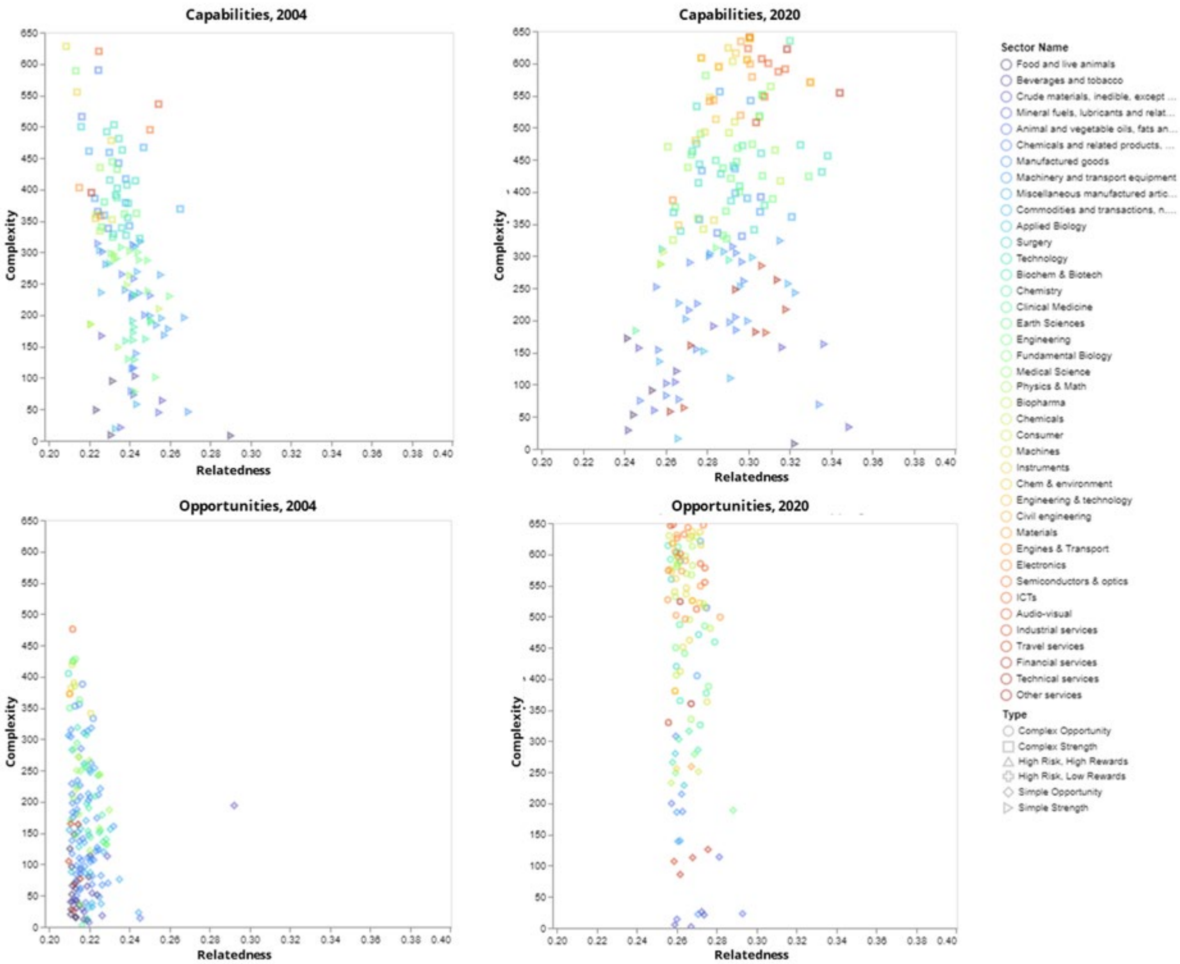
Not every innovation direction is equally groundbreaking. Economists consider the concepts of innovation relatedness and complexity to be helpful policy tools in guiding the selection of priorities. While the choices an economy could pursue are numerous, not all are equally related to pre-existing local capabilities. For example, given its ICT capabilities, a region such as Silicon Valley is more likely to innovate further in ICTs than in airplane technologies. The Toulouse region in France would likely be the opposite, as it is more related to airplane technologies than ICTs.

The innovation capabilities of countries, regions and companies condition their ability to generate new outcomes. Countries and regions tend to specialize in technologies and products that are closely related to their past capabilities. For instance, Silicon Valley’s capabilities are more related to ICTs, whereas Boston’s relate to health technologies and

Munich's relate to automotive technologies. Similarly, countries and regions can only specialize in a higher complexity technology once they have attained a higher relatedness to that technology. For example, EU regions have been found more likely to specialize in a complex product if it was more related to their recent specialization. In other words, the current relatedness of countries and regions influences their future specialization, especially for complex capabilities. This makes it hard for regions to leap to complex technologies without having first built the underlying capabilities. Therefore only a few regions and countries can attain more complex products and technologies.

Economists are increasingly suggesting that the complexity and relatedness framework is a useful toolbox for informing innovation policymaking, notably in support of smart specialization policies. By combining these metrics policymakers can understand which capabilities countries or regions possess and how rewarding they are in terms of complexity. Additionally, policymakers can explore which of the not-yet-developed capabilities can be more easily attained, given pre-existing capabilities.

Figure 20. Singapore's innovation capabilities and opportunities, 2001-2004 and 2017-2020



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Figure 20 plots the complexity of all innovation capabilities against their relatedness density in Singapore over two periods. Figure 20a shows the capabilities for which Singapore was specialized in 2001–2004, while Figure 20b shows the same for 2020. The change from 2001–2004 to 2020 indicates that Singapore successfully developed more complex capabilities. In 2001–2004, Singapore was mostly specialized in capabilities with a lower complexity (the bottom-right quadrant). By 2020, Singapore had managed to become specialized in capabilities with a higher complexity (the top-right quadrant).

How did Singapore do this? The process is at least partly explained by Figure 20c, which shows the opportunities that Singapore had in 2001–2004. By 2004, despite being not yet specialized, Singapore had a set of highly related capabilities (opportunities), the majority of which were low in complexity. Singapore focused on the uppermost opportunities and by 2020 it had managed to transform that high relatedness potential into concrete complex specialization. As a result, with its new set of capabilities, Figure 20d shows a handful of new opportunities, most of which are now in the high complexity spectrum. This current scenario is beneficial for the country, as it can continue to improve its complexity level and benefit from the rewards.

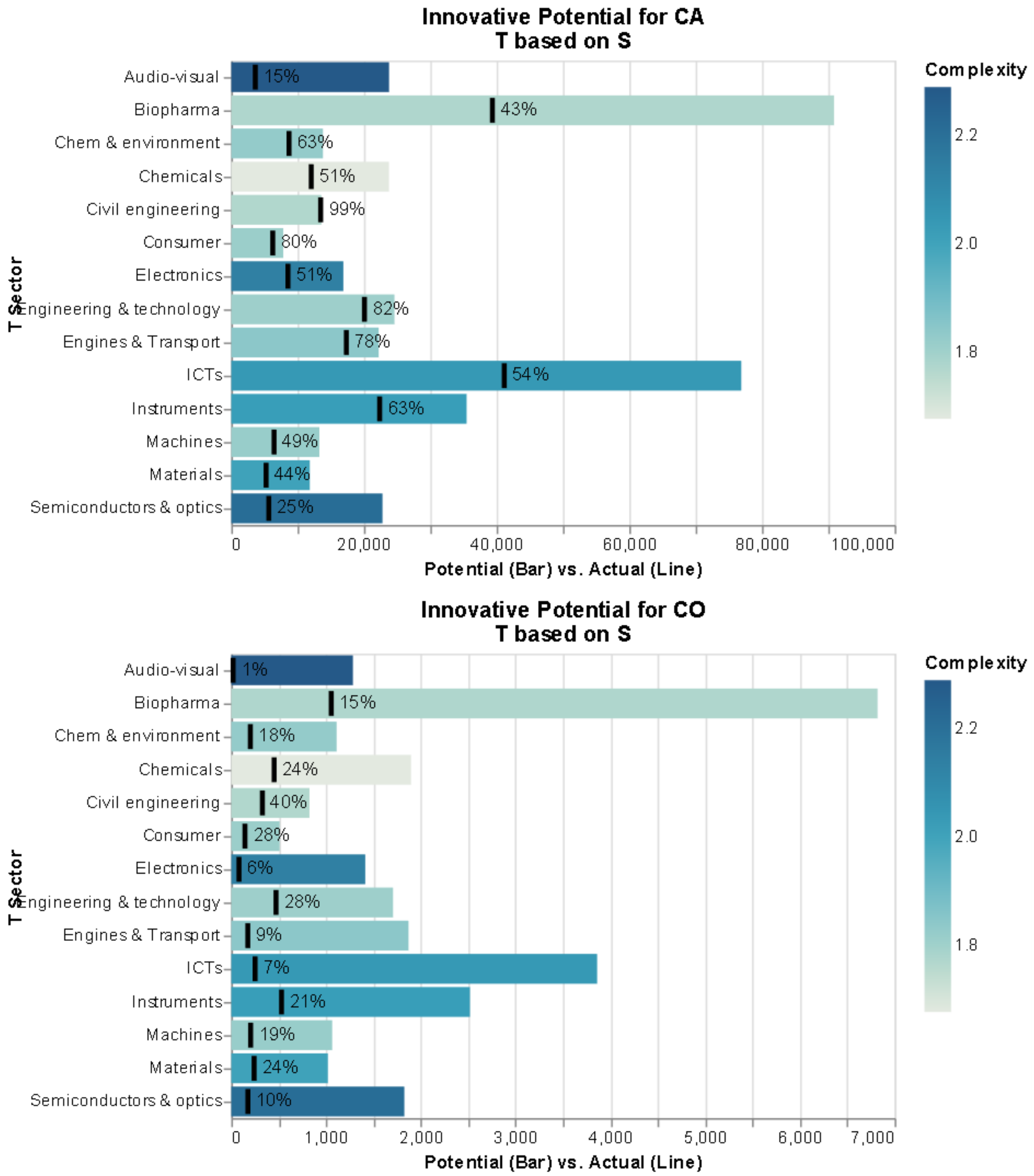
5.3 Tapping on innovative potential

National and regional innovation policies can also exploit the relatedness between capabilities of different dimensions. Indeed, countries or regions are specialized in very different areas when it comes to trade, patents and scientific publications. How do these areas relate to one another? Can scientific capabilities for example translate into economic or technological capabilities?

Capabilities might not be directly related and may not co-evolve together, although the indirect effect of scientific capabilities on the absorptive capacity of countries, regions and companies has been documented in the economic literature. Studies have shown that patenting activity across countries correlates with scientific publications but not every scientific publication necessarily leads to patenting. Similarly, other studies find that regional scientific capabilities in given scientific fields predict the development of related new technologies in the corresponding technological fields in the same regions. Recent studies find that countries are more likely to diversify in technologies that are related to existing scientific capabilities. A similar rationale follows the link between trade capabilities and the probability of entering new technological fields.

These connections can shed light on the untapped innovative potential of countries. The interplay between the three dimensions in the innovation frontier can help countries identify latent capabilities. Figure 21 contrasts the untapped technological potential of a medium-sized high-income economy (Canada) with the untapped technological potential of a middle-income economy (Colombia). Figure 21 uses the proximity connections between scientific and technological capabilities in the economies from cluster 1 (in Figure 17) to estimate the number of patents that could be expected to be seen in a country based on its scientific publications if it were the average country in cluster 1. It refers to potential output in a capability given the current outcome on related capabilities.

Figure 21. Technological innovation potential, Canada and Colombia



Note: 626 innovation capabilities based on scientific fields, IPC subclasses and product classification in scientific publications, international patent applications and exports data.
Sources: WoS SCIE, EPO PATSTAT, WIPO, UN COMTRADE.

Both countries have domains where, based on their scientific outputs, there is untapped technological potential. For Canada (Figure 21 top) there is room for improvement in three of the most complex domains – audiovisual, electronics, and semiconductors and optics. The average economy in cluster 1 would produce more patents if it had the same scientific outputs as Canada. For example, given its scientific production, Canada produces half as many patents in audiovisual technologies and two-thirds as many in chemical technologies compared to the average cluster 1 economy. In contrast, with the same scientific output, Canada produces 16 percent more patents in civil engineering technologies than the average cluster 1 economy in Figure 17.

This insight can be powerful when it comes to identifying missing links between the stakeholders in an innovation ecosystem. By looking into how these dimensions interact in a well-functioning ecosystem policymakers can prioritize between domains and zoom into the relations between academic institutions, industry and the IP system, to identify the particular constraints that are stopping the economy from reaching its full potential. For less diversified economies such as Colombia technological capabilities are less present at the international scale, and its observed patents are far from reaching their potential. Indeed, Colombia's transformation of scientific publications into international patents is in all fields less than 50 percent of that of the average cluster 1 economy. This is particularly relevant for biopharma and ICTs where Colombia produces a considerable related scientific output but realizes no more than 18 percent and six percent, respectively, of the technological transformation potential.

6 CONCLUSIONS, LIMITATIONS AND FURTHER RESEARCH

Our paper has explored the related empirical literature on how to measure innovation capabilities and presented new tools and evidence based on data drawn from scientific publications, international patents and exports. In doing so, it has explored the potential relevance of using measures of innovation capabilities to inform the design of innovation and industrial policy.

First, the paper has studied the need for a multidimensional measurement and an analysis of innovation capabilities. Categorizing innovation capabilities according to whether they are scientific, technological or production capabilities – measured by scientific publications, patents, and trade data – seems to be a useful approach to mapping the different innovation ecosystems that exist around the world. We also document a need for considering both relative and absolute specializations when analyzing innovation data, particularly in the case of patent and scientific publication data.

Second, to further understand the implications of a country's specialization in certain innovation capabilities, it is crucial to comprehend the quality of those capabilities. The complexity metrics explored in the paper add deeper insights that go far beyond how ubiquitous or rare any particular scientific, technological or production field might be. The empirical evidence shows that the development of more complex scientific, technological and production capabilities correlate with economic growth. Furthermore, the paper has identified differences in the level of complexity of capabilities between dimensions in general, highlighting the fact that the ability to produce technological innovations seems, overall, the most complex, and thus more rewarding, of the three dimensions analyzed.

Third, the paper documents that the capabilities existing in each innovation ecosystem are good predictors of new capabilities. The dynamics and interactions of the relatedness and complexity of innovation capabilities present an useful framework for understanding the progression toward the economic and technological development of an innovation ecosystem – either local, regional or national. These interconnected concepts and metrics can help policymakers to adopt a strategic approach that encompasses the co-evolution of different domains and their interdependencies. By doing so, economies can address binding constraints, stimulate positive externalities, and promote a resilient innovation ecosystem.

Lastly, the paper has documented the importance of innovation diversification for countries and the relationship between science, technology, and production. The ever-changing landscape of capabilities and their relatedness underscores the need for strategic diversification. This evolution is not a one-size-fits-all process. Instead, it allows countries to choose from diverse paths based on their unique circumstances. Some may opt for a strategy that builds progressively on existing skills, while others may aim to accelerate the transition to a new field by targeting less related domains, known as leapfrogging. The choice of strategy should be well-timed and align with a country's specific goals and resource availability. The timing of a venture into unrelated activities is of vital importance. Pursuing such a venture either too early or too late can result in missed opportunities and a waste of resources. Policymakers need to be able to recognize a narrow window of opportunity when it opens and have the related capabilities in place.

6.1 Limitations

There are also some important limitations to note. First, while very important, the discussed scientific, technological and production dimensions are not the only dimensions related to innovation capabilities. Other dimensions could include entrepreneurial, educational, financial or governmental aspects – such as their conditions and institutional quality – to name a few.

Second, the scientific, technological and production dimensions are not perfectly measured by scientific papers, patents and exports. For instance, non-patentable technologies and non-tradable goods also contribute to the innovation capabilities of an ecosystem. Yet, these two dimensions are poorly measured by scientific publications, patents and trade data. Web of Science – and other scientific publication data sources – have known limitations in terms of journal coverage, particularly in terms language and geographical bias.

Third, the country level analysis of these three innovation dimensions might be too aggregated, confounding regional capabilities of countries with large territories and urban capabilities with rural ones. For example, being separated by almost five thousand kilometers, it cannot be assumed that the aggregated capabilities of Silicon Valley and New York City apply to each other. Similarly, the innovation capabilities of large urban centers – such as the mentioned Silicon Valley and New York City – do not apply to many rural areas in the center of the United States.

Fourth, some caution is needed when interpreting the innovation capability mapping and complexity estimation. The results are sensitive to quality of data and the countries and fields included. Similarly, the binarization of capabilities can be sensitive to threshold modifications. Another relevant word caution refers to the complexity and economic growth correlation. In most cases, economic research has found a strong correlation without a strong empirical setting to test causation. Moreover, there is still a limited conceptualization and understanding of the mechanisms through which these relationships are working, which limits the potential empirical tests.

6.2 Further research

In sum, managing innovation capabilities and their relatedness is pivotal for those countries seeking long-term growth and competitiveness in an ever-evolving global economic landscape. By embracing the principles of complexity and smart specialization, comprehending related and unrelated capabilities, and making well-informed strategic decisions, countries can position themselves for success and sustainability in economic and technological development.

In order to better inform the innovation policy design, more research is needed to further understand the innovation capabilities and provide better measures for their appraisal. This will require further exploration of the strengths and limitations of the proposed method; as well as overcoming the limitations already surveyed.

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ANNEXES

List of domains

P - 0: Food and live animals; P - 1: Beverages and tobacco; P - 2: Crude materials, inedible, except fuels; P - 3: Mineral fuels, lubricants and related materials; P - 4: Animal and vegetable oils, fats and waxes; P - 5: Chemicals and related products, n.e.s.; P - 6: Manufactured goods; P - 7: Machinery and transport equipment; P - 8: Miscellaneous manufactured articles; P - 9: Commodities and transactions, n.e.s.; S - 1: Applied Biology; S - 11: Surgery; S - 12: Technology; S - 2: Biochem & Biotech; S - 3: Chemistry; S - 4: Clinical Medicine; S - 5: Earth Sciences; S - 6: Engineering; S - 7: Fundamental Biology; S - 8: Medical Science; S - 9: Physics & Math; T - 6: Biopharma; T - 7: Chemicals; T - 13: Consumer; T - 11: Machines; T - 5: Instruments; T - 9: Chem & environment; T - 10: Engineering & technology; T - 14: Civil engineering; T - 8: Materials; T - 12: Engines & Transport; T - 1: Electronics; T - 4: Semiconductors & optics; T - 3: ICTs; T - 2: Audio-visual; P - A: Industrial services; P - B: Travel services; P - C: Financial services; P - D: Technical services; P - E: Other services.

List of fields

P - 1: Live animals other than animals of division 03; P - 11: Meat of bovine animals, fresh, chilled or frozen; P - 12: Meat, other than of bovine animals, and edible offal, fresh, chilled or frozen (except meat and meat offal not suitable for human consumption); P - 16: Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal; P - 17: Meat and edible meat offal, prepared or preserved n.e.s.; P - 22: Milk and cream and milk products other than butter or cheese; P - 23: Butter and other fats and oils derived from milk; P - 24: Cheese and curd; P - 25: Birds' eggs and egg yolks, fresh, dried or otherwise preserved, sweetened or not; egg albumin; P - 34: Fish, fresh (live or dead), chilled or frozen; P - 35: Fish, dried, salted r in brine; smoked fish (whether or not cooked before or during the smoking process); flours, meals n pellets r fish, fit f human consumption; P - 36: Crustaceans molluscs, aquatic invertebrates fresh (live/dead) ch salted etc.; crustaceans in shell cooked by steam or boiling water whether or not ch frozen dried flour meals pellets human consumption; P - 37: Fish, crustaceans, molluscs and other aquatic invertebrates, prepared or preserved, n.e.s.; P - 41: Wheat (including spelt) and meslin, unmilled; P - 42: Rice; P - 43: Barley, unmilled; P - 44: Maize (not including sweet corn) unmilled; P - 45: Cereals, unmilled (other than wheat, rice, barley and maize); P - 46: Meal and flour of wheat and flour of meslin; P - 47: Cereal meals and flours, n.e.s.; P - 48: Cereal preparations and preparations of flour or starch of fruits or vegetables; P - 54: Vegetables, fresh, chilled, frozen or simply preserved; roots, tubers and other edible vegetable products, n.e.s., fresh or dried; P - 56: Vegetables, roots and tubers, prepared or preserved, n.e.s.; P - 57: Fruit and nuts (not including oil nuts), fresh or dried; P - 58: Fruit preserved, and fruit preparations (excluding fruit juices); P - 59: Fruit juices (incl. grape must) and vegetable juices, unfermented and not containing added spirit, whether or not containing added sweetening matter; P - 61: Sugars, molasses, and honey; P - 62: Sugar confectionery; P - 71: Coffee and coffee substitutes; P - 72: Cocoa; P - 73: Chocolate and other food preparations containing cocoa, n.e.s.; P - 74: Tea and mate; P - 75: Spices; P - 81: Feeding stuff for animals (not including unmilled cereals); P - 91: Margarine and shortening; P - 98: Edible products and preparations, n.e.s.; P - 111: Nonalcoholic beverages, n.e.s.; P - 112: Alcoholic beverages; P - 121: Tobacco, unmanufactured; tobacco refuse; P - 122: Tobacco, manufactured (whether or not containing tobacco substitutes); P - 211: Hides and skins (except furskins), raw; P - 212: Furskins, raw (including furskin heads, tails and other pieces or cuttings, suitable for furriers' use); P - 222: Oil seeds and oleaginous fruits used for the extraction of soft fixed vegetable oils (excluding flours and meals); P - 223: Oil seeds and oleaginous fruits, whole or broken, of a kind used for extracting other fixed vegetalbe oils (including their flours and meals, n.e.s.); P - 231: Natural rubber, balata, gutta-percha, guayule, chicle and similar natural gums, in primary forms (including latex) or in plates, sheets or strip; P - 232: Synthetic rubber; reclaimed rubber; waste, pairings and scrap of unhardened rubber; P - 244: Cork, natural, raw and waste (including natural cork in blocks or sheets); P - 245: Fuel wood (excluding wood waste) and wood charcoal; P - 246: Wood in chips or particles and wood waste; P - 247: Wood in the rough or roughly squared; P - 248: Wood, simply worked and railway sleepers of wood; P - 251: Pulp and waste paper; P - 261: Silk textile fibers; P - 263: Cotton textile fibers; P - 264: Jute and other textile bast fibers, n.e.s., raw or processed but not spun; tow and waste of these fibres (including yarn waste and garnetted stock); P - 265: Vegetable textile fibers (other than cotton and jute), raw or processed but not spun; waste of these fibers; P - 266: Synthetic fibers suitable for spinning; P - 267: Manmade fibers, n.e.s. suitable for spinning and waste of manmade fibers; P - 268: Wool and other animal hair (including wool tops); P - 269: Worn clothing and other worn textile articles; rags; P - 272: Fertilizer, crude, except those of division 56, (imports only); P - 273: Stone, sand and gravel; P - 274: Sulfur and unroasted iron pyrites; P - 277: Natural abrasives, n.e.s. (including industrial diamonds); P - 278: Crude minerals, n.e.s.; P - 281: Iron ore and concentrates; P - 282: Ferrous waste and scrap; remelting ingots of iron or steel; P - 283: Copper ores and concentrates; copper mattes; cement copper; P - 284: Nickel ores and concentrates; nickel mattes, nickel oxide sinters and other intermediate products of nickel metallurgy; P - 285: Aluminum ores and concentrates (including alumina); P - 286: Ores and concentrates of uranium or thorium; P - 287: Ores and concentrates of base metals, n.e.s.; P - 288: Nonferrous base metal waste and scrap, n.e.s.; P - 289: Ores and concentrates of precious metals; waste, scrap and sweepings of precious metals (other than gold); P - 291: Crude animal materials, n.e.s.; P - 292: Crude vegetable materials, n.e.s.; P - 321: Coal, pulverized or not, but not agglomerated; P - 322: Briquettes, lignite and peat; P - 325: Coke and semicoke (including char) of coal, of lignite or of peat, agglomerated or not; retort carbon; P - 333: Petroleum oils and oils from bituminous minerals, crude; P - 334: Petroleum oils and oils from bituminous minerals (other than crude), and products therefrom containing 70% (by wt) or more of these oils, n.e.s.; P - 335: Residual petroleum products, n.e.s. and related materials; P - 342: Liquefied propane and butane; P - 343: Natural gas, whether or not liquefied; P - 344: Petroleum gases and other gaseous hydrocarbons, n.e.s.; P - 345: Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons; P - 351: Electric current; P - 411: Animal oils and fats; P - 421: Fixed vegetable fats and oils, soft, crude, refined or fractionated; P - 422: Fixed vegetable fats and oils (other than soft), crude, refined or fractionated; P - 431: Animal or vegetable fats and oils processed; waxes and inedible mixtures or preparations of animal or vegetable fats or oils, n.e.s.; P - 511: Hydrocarbons, n.e.s. and their halogenated, sulfonated, nitrated or nitrosated derivatives; P - 512: Alcohols, phenols, phenol-alcohols and their halogenated, sulfonated, nitrated or nitrosated derivatives; P - 513: Carboxylic acids and anhydrides, halides, peroxides and peroxyacids; their halogenated, sulfonated, nitrated or nitrosated derivatives; P - 514: Nitrogen-function compounds; P - 515: Organo-inorganic compounds, heterocyclic compounds, nucleic acids and their salts; P - 516: Organic chemicals, n.e.s.; P - 522: Inorganic chemical elements, oxides and halogen salts; P - 523: Metallic salts and peroxysalts of inorganic acids; P - 524: Inorganic chemicals, n.e.s.; organic and inorganic compounds of precious metals; P - 525: Radioactive and associated materials; P - 531: Synthetic organic coloring matter and color lakes and preparations based thereon; P - 532: Dyeing and tanning extracts, and synthetic tanning materials; P - 533: Pigments, paints, varnishes and related materials; P - 541: Medicinal and pharmaceutical products, other than medicaments (of group 542); P - 542: Medicaments (including veterinary medicaments); P - 551: Essential oils, perfume and flavor materials; P - 553: Perfumery, cosmetics, or toilet preparations, excluding soaps; P - 554: Soap, cleansing and polishing preparations; P - 562: Fertilizers (exports include group 272; imports exclude group 272); P - 571: Polymers of ethylene, in primary forms; P - 572: Polymers of styrene, in primary forms; P - 573: Polymers of vinyl chloride or other halogenated olefins, in primary forms; P - 574: Polyacetals, other polyethers and epoxide resins, in primary forms; polycarbonates, alkyd resins and other polyesters, in primary forms; P - 575: Plastics, n.e.s., in primary forms; P - 579: Waste, parings and scrap, of plastics; P - 581: Tubes, pipes and hoses of plastics; P - 582: Plates, sheets, film, foil and strip of plastics; P - 583: Monofilament with a cross-sectional dimension exceeding 1 mm, rods, sticks and profile shapes of plastics, not more than surface-worked; P - 591: Insecticides, fungicides, herbicides, plant growth regulators, etc., disinfectants and similar products, put up or packed for retail sale, etc.; P - 592: Starches, inulin and wheat gluten; albuminoidal substances; glues; P - 593: Explosives and pyrotechnic products; P - 597: Prepared additives for mineral oils etc.; liquids for hydraulic transmissions; antifreezes and deicing fluids; lubricating preparations; P - 598: Miscellaneous chemical products, n.e.s.; P - 599: Redisual products of the chemical or allied industries, nes; municipal waste; sewage sludge; other wastes; P - 611: Leather; P - 612: Manufactures of leather or composition leather, n.e.s.; saddlery and harness; P - 613: Furskins, tanned or dressed (including pieces or cuttings), assembled or unassembled without the addition of other materials, other than apparel, etc.; P - 621: Materials of rubber, including pastes, plates, sheets, rods, thread, tubes, etc.; P - 625: Rubber tires, interchangeable tire treads, tire flaps and inner tubes for wheels of all kinds; P - 629: Articles of rubber, n.e.s.; P - 633: Cork manufactures; P - 634: Veneers, plywood, particle board, and other wood, worked, n.e.s.; P - 635: Wood manufactures, n.e.s.; P - 641: Paper and paperboard; P - 642: Paper and paperboard, cut to size or shape, and articles of paper or paperboard; P - 651: Textile yarn; P - 652: Cotton fabrics, woven (not including narrow or special fabrics); P - 653: Woven fabrics of manmade textile materials (not including narrow or special fabrics); P - 654: Woven fabrics of textile materials, other than cotton or manmade fibers and narrow or special fabrics; P - 655: Knitted or crocheted fabrics (including tubular knit fabrics, n.e.s., pile fabrics and open-work fabrics), n.e.s.; P - 656: Tulles, lace, embroidery, ribbons, trimmings and other small wares; P - 657: Special yarns, special textile fabrics and related products; P - 658: Made-up articles, wholly or chiefly of textile materials, n.e.s.; P - 659: Floor coverings, etc.; P - 661: Lime, cement, and fabricated construction materials, except glass and clay materials; P - 662: Clay construction materials and refractory construction materials; P - 663: Mineral manufactures, n.e.s.; P - 664: Glass; P - 665: Glassware; P - 666: Pottery; P - 667: Pearls, precious and semiprecious stones, unworked or worked; P - 671: Pig iron and spiegeleisen, sponge iron, iron or steel granules and powders and ferroalloys; P - 672: Iron or steel ingots and other primary forms, and semifinished products of iron or steel; P - 673: Iron or nonalloy steel flat-rolled products, not clad, plated or coated; P - 674: Iron and nonalloy steel flat-rolled products, clad, plated or coated; P - 675: Alloy steel flat-rolled products; P - 676: Iron and steel bars, rods, angles, shapes and sections, including sheet piling; P - 677: Iron and steel rails and railway track construction material; P - 678: Iron and steel wire; P - 679: Iron and steel tubes, pipes and hollow profiles, fittings for tubes and pipes; P - 681: Silver, platinum and other platinum group metals; P - 682: Copper; P - 683: Nickel; P - 684: Aluminum; P - 685: Lead; P - 686: Zinc; P - 687: Tin; P - 689: Miscellaneous nonferrous base metals employed in metallurgy and cermets; P - 691: Metal structures and parts, n.e.s., of iron, steel or aluminum; P - 692: Metal containers for storage or transport; P - 693: Wire products (excluding insulated electrical wiring) and fencing grills; P - 694: Nails, screws, nuts, bolts, rivets and similar articles, of iron, steel, copper or aluminum; P - 695: Tools for use in the hand or in machines; P - 696: Cutlery; P - 697: Household equipment of base metal, n.e.s.; P - 699: Manufactures of base metal, n.e.s.; P - 711: Steam or other vapor generating boilers, super-heated water boilers and auxiliary plant for use therewith; and parts thereof; P - 712: Steam turbines and other vapor turbines, and parts thereof, n.e.s.; P - 713: Internal combustion piston engines and parts thereof, n.e.s.; P - 714: Engines and motors, nonelectric (other than steam turbines, internal combustion piston engines and power generating machinery); parts thereof, n.e.s.; P - 716: Rotating electric plant and parts thereof, n.e.s.; P - 718: Power generating machinery and parts thereof, n.e.s.; P - 721: Agricultural machinery (excluding tractors) and parts thereof; P - 722: Tractors (other than mechanical handling equipment); P - 723: Civil engineering and contractors' plant and equipment; P - 724: Textile and leather machinery, and parts thereof, n.e.s.; P - 725: Paper mill and pulp mill machinery, paper cutting machines and machinery for the manufacture of paper articles; parts thereof; P - 726: Printing and bookbinding machinery, and parts thereof; P - 727: Food-processing machines (excluding domestic); P - 728: Machinery and equipment specialized for particular industries, and parts thhereof, n.e.s.; P - 731: Machine tools working by removing metal or other material; P - 733: Machine tools for working metal, sintered metal carbides or cermets, without removing material; P - 735: Parts and accessories suitable for use solely or principally with metal working machine tools, whether or not removing metal; hand held tool holders; P - 737: Metalworking machinery (other than machine tools) and parts thereof, n.e.s.; P - 741: Heating and cooling equipment and parts thereof, n.e.s.; P - 742: Pumps for liquids, whether or not fitted with a measuring device; liquid elevators; parts for such pumps and liquid elevators; P - 743: Pumps (not for liquids), air or gas compressors and fans; ventilating hoods incorporating a fan; centrifuges; filtering etc. apparatus; parts thereof; P - 744: Mechanical handling equipment, and parts thereof, n.e.s.; P - 745: Nonelectrical machinery, tools and mechanical apparatus, and parts thereof, n.e.s.; P - 746: Ball or roller bearings; P - 747: Taps, cocks, valves and similar appliances for pipes, boiler shells, tanks, etc. (including pressure and temperature controlled valves); P - 748: Transmission shafts and cranks; bearing housings and plain shaft bearings; gears and gearing; ball screws; gear boxes, clutches, etc.; parts thereof; P - 749: Nonelectric parts and accessories of machinery, n.e.s.; P - 751: Office machines; P - 752: Automatic data processing machines and units thereof; magnetic or optical readers; machines transcribing coded media and processing such data, n.e.s.; P - 759: Parts and accessories suitable for use solely or principally with office machines or automatic data processing machines; P - 761: Tv receivers (including video monitors & projectors) wheth r nt incorp radiobroadcast receivers or sound or video recording or reproducing apparatus; P - 762: Radio-broadcast receivers, whether or not incorporating sound recording or reproducing apparatus or a clock; P - 763: Sound recorders or reproducers; television image and sound recorders or reproducers; P - 764: Telecommunications equipment, n.e.s.; and parts, n.e.s., and accessories of apparatus falling within telecommunications, etc.; P - 771: Electric power machinery (other than rotating electric plant of power generating machinery) and parts thereof; P - 772: Electrical apparatus for switching or protecting electrical circuits or for making connections to or in electrical circuits (excluding telephone etc.); P - 773: Equipment for distributing electricity, n.e.s.; P - 774: Electro-diagnostic apparatus for medical, surgical, dental or veterinary sciences and radiological apparatus; P - 775: Household type electrical and nonelectrical equipment, n.e.s.; P - 776: Thermionic, cold cathode or photocathode valves and tubes; diodes, transistors and similar semiconductor devices; integrated circuits, etc.; parts; P - 778: Electrical machinery and apparatus, n.e.s.; P - 781: Motor cars and other motor vehicles principally designed for the transport of persons (not public transport), including station wagons and racing cars; P - 782: Motor vehicles for the transport of goods and special purpose motor vehicles; P - 783: Road motor vehicles, n.e.s.; P - 784: Parts and accessories for tractors, motor cars and other motor vehicles, trucks, public-transport vehicles and road motor vehicles n.e.s.; P - 785: Motorcycles (including mopeds) and cycles, motorized and not motorized; invalid carriages; P - 786: Trailers and semi-trailers; other vehicles, not mechanically propelled; specially designed and equipped transport containers; P - 791: Railway vehicles (including hovertrains) and associated equipment; P - 792: Aircraft and associated equipment; spacecraft (including satellites) and spacecraft launch vehicles; and parts thereof; P - 793: Ships, boats (including hovercraft) and floating structures; P - 811: Prefabricated buildings; P - 812: Sanitary, plumbing and heating fixtures and fittings, n.e.s.; P - 813: Lighting fixtures and fittings, n.e.s.; P - 821: Furniture and parts thereof; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; P - 831: Trunks, suitcases, vanity cases, binocular and camera cases, handbags, wallets, etc. of leather, etc.; travel sets for personal toilet, sewing, etc.; P - 841: Men's or boys' coats, jackets, suits, trousers, shirts, underwear etc. of woven textile fabrics (except swimwear and coated or laminated apparel); P - 842: Women's or girls' coats, capes, jackets, suits, trousers, dresses, skirts, underwear, etc. of woven textiles (except swimwear and coated etc. apparel); P - 843: Men's or boys' coats, capes, jackets, suits, blazers, trousers, shirts, etc. (except swimwear or coated apparel), knitted or crocheted textile fabric; P - 844: Women's or girls' coats, capes, jackets, suits, trousers, dresses, underwear, etc. (except swimwear and coated etc. apparel), knitted or crocheted; P - 845: Articles of apparel, of textile fabrics, whether or not knitted or crocheted, n.e.s.; P - 846: Clothing accessories, of textile fabrics, whether or not knitted or crocheted (other than those for babies); P - 848: Articles of apparel and clothing accessories of other than textile fabrics; headgear of all materials; P - 851: Footwear; P - 871: Optical instruments and apparatus, n.e.s.; P - 872: Instruments and appliances, n.e.s., for medical, surgical, dental or veterinary purposes; P - 873: Meters and counters, n.e.s.; P - 874: Measuring, checking, analysing and controlling instruments and apparatus, n.e.s.; P - 881: Photographic apparatus and equipment, n.e.s.; P - 882: Photographic and cinematographic supplies; P - 883: Cinematographic film, exposed and developed, whether or not incorporating sound track or consisting only of sound track; P - 884: Optical goods, n.e.s.; P - 885: Watches and clocks; P - 891: Arms and ammunition; P - 892: Printed matter; P - 893: Articles, n.e.s. of plastics; P - 894: Baby carriages, toys, games and sporting goods; P - 895: Office and stationery supplies, n.e.s.; P - 896: Works of art, collectors' pieces and antiques; P - 897: Jewelry, goldsmiths' and silversmiths' wares, and other articles of precious or semiprecious materials, n.e.s.; P - 898: Musical instruments, parts and accessories thereof; records, tapes and other sound or similar recordings (excluding photographic film, etc.); P - 899: Miscellaneous manufactured articles, n.e.s.; P - 931: Special transactions and commodities not classified according to kind; P - 961: Coin (other than gold coin), not being legal tender; P - 971: Gold, nonmonetary (excluding gold ores and concentrates); S - 110: Entomology; S - 111: Fisheries; S - 112: Forestry; S - 113: Agriculture, Dairy & Animal Science; S - 114: Agronomy; S - 115: Agriculture, Multidisciplinary; S - 116: Mycology; S - 117: Soil Science; S - 118: Biodiversity & Conservation; S - 119: Biodiversity Conservation; S - 120: Horticulture; S - 121: Agricultural Engineering; S - 122: Materials Science, Textiles; S - 123: Ornithology; S - 1101: Surgery; S - 1102: Cardiovascular System & Cardiology; S - 1103:

Urology & Nephrology; S - 1104: Cardiac & Cardiovascular Systems; S - 1105: Obstetrics & Gynecology; S - 1106: Ophthalmology; S - 1107: Orthopedics; S - 1108: Dentistry, Oral Surgery & Medicine; S - 1109: Anesthesiology; S - 1201: Science & Technology - Other Topics; S - 1202: Computer Science; S - 1203: Telecommunications; S - 1204: Nuclear Science & Technology; S - 1205: Automation & Control Systems; S - 1206: Operations Research & Management Science; S - 1207: Computer Science, Information Systems; S - 1208: Computer Science, Artificial Intelligence; S - 1209: Computer Science, Theory & Methods; S - 1210: Computer Science, Interdisciplinary Applications; S - 1211: Acoustics; S - 1212: Computer Science, Software Engineering; S - 1213: Imaging Science & Photographic Technology; S - 1214: Remote Sensing; S - 1215: Computer Science, Hardware & Architecture; S - 1216: Medical Informatics; S - 1217: Information Science & Library Science; S - 1218: Robotics; S - 1219: Green & Sustainable Science & Technology; S - 1220: Computer Science, Cybernetics; S - 1221: Logic; S - 1222: Architecture; S - 201: Biochemistry & Molecular Biology; S - 202: Pharmacology & Pharmacy; S - 203: Cell Biology; S - 204: Biotechnology & Applied Microbiology; S - 205: Genetics & Heredity; S - 301: Chemistry; S - 302: Materials Science; S - 303: Chemistry, Multidisciplinary; S - 304: Materials Science, Multidisciplinary; S - 305: Chemistry, Physical; S - 306: Polymer Science; S - 307: Chemistry, Analytical; S - 308: Chemistry, Organic; S - 309: Electrochemistry; S - 310: Nanoscience & Nanotechnology; S - 311: Crystallography; S - 312: Chemistry, Inorganic & Nuclear; S - 313: Chemistry, Applied; S - 314: Chemistry, Medicinal; S - 315: Materials Science, Coatings & Films; S - 316: Materials Science, Ceramics; S - 317: Materials Science, Composites; S - 318: Materials Science, Characterization & Testing; S - 319: Materials Science, Paper & Wood; S - 401: Oncology; S - 402: General & Internal Medicine; S - 403: Radiology, Nuclear Medicine & Medical Imaging; S - 404: Psychiatry; S - 405: Clinical Neurology; S - 406: Pediatrics; S - 407: Medicine, General & Internal; S - 408: Pathology; S - 409: Dermatology; S - 410: Toxicology; S - 411: Health Care Sciences & Services; S - 412: Rheumatology; S - 413: Critical Care Medicine; S - 414: Otorhinolaryngology; S - 415: Allergy; S - 416: Rehabilitation; S - 417: Emergency Medicine; S - 418: Tropical Medicine; S - 419: Andrology; S - 501: Environmental Sciences & Ecology; S - 502: Astronomy & Astrophysics; S - 503: Environmental Sciences; S - 504: Geology; S - 505: Marine & Freshwater Biology; S - 506: Water Resources; S - 507: Meteorology & Atmospheric Sciences; S - 508: Geochemistry & Geophysics; S - 509: Geosciences, Multidisciplinary; S - 510: Oceanography; S - 511: Engineering, Environmental; S - 512: Paleontology; S - 513: Mineralogy; S - 514: Geography, Physical; S - 515: Physical Geography; S - 516: Engineering, Geological; S - 517: Limnology; S - 601: Engineering; S - 602: Engineering, Electrical & Electronic; S - 603: Energy & Fuels; S - 604: Metallurgy & Metallurgical Engineering; S - 605: Mechanics; S - 606: Engineering, Chemical; S - 607: Instruments & Instrumentation; S - 608: Thermodynamics; S - 609: Engineering, Mechanical; S - 610: Engineering, Civil; S - 611: Construction & Building Technology; S - 612: Engineering, Biomedical; S - 613: Engineering, Multidisciplinary; S - 614: Engineering, Manufacturing; S - 615: Engineering, Industrial; S - 616: Transportation; S - 617: Engineering, Aerospace; S - 618: Mining & Mineral Processing; S

- 619: Engineering, Petroleum; S - 620: Transportation Science & Technology; S - 621: Engineering, Ocean; S - 622: Engineering, Marine; S - 701: Neurosciences & Neurology; S - 702: Neurosciences; S - 703: Microbiology; S - 704: Biophysics; S - 705: Physiology; S - 706: Reproductive Biology; S - 707: Biochemical Research Methods; S - 708: Virology; S - 709: Evolutionary Biology; S - 710: Developmental Biology; S - 711: Mathematical & Computational Biology; S - 712: Medical Laboratory Technology; S - 713: Parasitology; S - 714: Materials Science, Biomaterials; S - 715: Anatomy & Morphology; S - 716: Neuroimaging; S - 717: Microscopy; S - 718: Cell & Tissue Engineering; S - 801: Immunology; S - 802: Endocrinology & Metabolism; S - 803: Gastroenterology & Hepatology; S - 804: Hematology; S - 805: Respiratory System; S - 806: Infectious Diseases; S - 807: Medicine, Research & Experimental; S - 808: Research & Experimental Medicine; S - 809: Peripheral Vascular Disease; S - 901: Physics; S - 902: Mathematics; S - 903: Physics, Applied; S - 904: Optics; S - 905: Physics, Condensed Matter; S - 906: Physics, Multidisciplinary; S - 907: Mathematics, Applied; S - 908: Physics, Atomic, Molecular & Chemical; S - 909: Spectroscopy; S - 910: Physics, Particles & Fields; S - 911: Physics, Mathematical; S - 912: Statistics & Probability; S - 913: Physics, Nuclear; S - 914: Physics, Fluids & Plasmas; S - 915: Mathematics, Interdisciplinary Applications; T - A01-18: Food from agriculture; forestry; animal husbandry; hunting; trapping; fishing; T - A21-18: Baking; doughs for baking; T - A23-18: Foods or foodstuffs; their treatment, not covered by other classes; T - A61-14: Medical or veterinary science; hygiene - Chemistry; T - A61-16: Medical or veterinary science; hygiene - Pharmaceuticals; T - C07-14: Organic chemistry; T - C07-15: Organic chemistry - Biotechnology; T - C12-15: Biochemistry; microbiology; enzymology; mutation or genetic engineering; T - C12-18: Biochemistry; beer; spirits; wine; vinegar; T - C13-18: Sugar industry - Chemistry; T - C40: Combinatorial technology; T - A01-19: Chemical materials from Agriculture; forestry; animal husbandry; hunting; trapping; fishing; T - A01-29: Machines for agriculture; forestry; animal husbandry; hunting; trapping; fishing; T - A21-29: Baking; equipment for making or processing doughs; T - A22: Butchering; meat treatment; processing poultry or fish; T - A23-29: Machines for foods or foodstuffs; their treatment, not covered by other classes; T - B02-29: Machines for crushing, pulverising, or disintegrating; preparatory treatment of grain for milling; T - B28: Working cement, clay, or stone; T - B29: Working of plastics; working of substances in a plastic state in general; T - B33: Additive manufacturing technology; T - C03-29: Machines for glass; mineral or slag wool; T - C05: Fertilisers; manufacture thereof; T - C06: Explosives; matches; T - C08-17: Organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon; T - C08-29: Machines for organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon; T - C09: Dyes; paints; polishes; natural resins; adhesives; compositions not otherwise provided for; applications of materials not otherwise provided for; T - C10: Petroleum, gas or coke industries; technical gases containing carbon monoxide; fuels; lubricants; peat; T - C11: Animal or vegetable oils, fats, fatty substances or waxes; fatty acids therefrom; detergents; candles; T - C12-29: Machines for beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering; T - C13-29: Sugar industry machines; T - F41: Weapons; T - F42: Ammunition; blasting; T - A24: Tobacco; cigars; cigarettes; smokers' requisites; T - A41-34: Wearing apparel; T - A42: Headwear; T - A43-34: Footwear; T - A44: Haberdashery; jewellery; T - A45: Hand or travelling articles; T - A46-34: Other brushware; T - A47: Furniture; domestic articles or appliances; coffee mills; spice mills; suction cleaners in general; T - A62-34: Life-saving; fire-fighting - Goods; T - A63: Sports; games; amusements; T - B42: Bookbinding; albums; files; special printed matter; T - B43: Writing or drawing implements; bureau accessories; T - B44: Decorative arts; T - B68: Saddlery; upholstery; T - D04-34: Other braiding; lace-making; knitting; trimmings; non-woven fabrics; T - D06-34: Articles for treatment of textiles or the like; laundering; flexible materials not otherwise provided for; T - D07: Ropes; cables other than electric; T - F25-34: Refrigeration or cooling apparatus; T - G10-34: Musical instruments; acoustics; T - A41-28: Appliances or methods for wearing apparel; T - A43-28: Footwear machines; T - A46-28: Brushware; T - A62-26: Life-saving; fire-fighting - Machines; T - B21: Mechanical metal-working without essentially removing material; punching metal; T - B23: Machine tools; metal-working not otherwise provided for; T - B24: Grinding; polishing; T - B25-25: Handles for hand implements; manipulators; T - B25-26: Hand tools; portable power-driven tools; workshop equipment; T - B26: Hand cutting tools; cutting; severing; T - B27: Working or preserving wood or similar material; nailing or stapling machines in general; T - B30: Presses; T - B31: Making articles of paper or cardboard; working paper or cardboard; T - B41: Printing; lining machines; typewriters; stamps; T - B65-25: Conveying; packing; storing; handling thin or filamentary material; T - B66: Hoisting; lifting; hauling; T - B67: Opening or closing bottles, jars or similar containers; liquid handling; T - C14-28: Skins; hides; pelts; leather machines; T - D01: Natural or man-made threads or fibres; spinning; T - D02: Yarns; mechanical finishing of yarns or ropes; warping or beaming; T - D03: Weaving; T - D04-28: Braiding; lace-making; knitting; trimmings; non-woven fabrics; T - D05: Sewing; embroidering; tufting; T - D06-28: Machines for treatment of textiles or the like; laundering; flexible materials not otherwise provided for; T - D21: Paper-making; production of cellulose; T - A61-13: Medical or veterinary science; hygiene - Medical technology; T - G01-10: Measuring; testing; T - G01-11: Measuring; testing biological materials; T - G04: Horology; T - G05-12: Systems for controlling; regulating; T - G07: Checking-devices; T - G08-12: Signalling; T - G09-12: Instruments for educating; cryptography; display; advertising; seals; T - G12: Instrument details; T - G16-13: Information and communication technology [ICT] specially adapted for medical technology; T - H05-13: Electric techniques for medical technology; T - A62-24: Life-saving; fire-fighting - Chemicals; T - B01-23: Physical or chemical processes or apparatus in general; T - B01-24: Physical or chemical processes or apparatus in general - Environmental; T - B02-23: Crushing, pulverising, or disintegrating; preparatory treatment of grain for milling; T - B03: Separation of solid materials using liquids or using pneumatic tables or jigs; magnetic or electrostatic separation of solid materials from solid materials or fluids; separation by high-voltage electric fields; T - B04: Centrifugal apparatus or machines for carrying-out physical or chemical processes; T - B05-23: Spraying or atomising in general; T - B06: Generating or transmitting mechanical vibrations in general; T - B07: Separating solids from solids; sorting; T - B08: Cleaning; T - B09: Disposal of solid waste; reclamation of contaminated soil; T - B65-24: Environmental technology for conveying; packing; storing; handling thin or filamentary material; T - C02: Treatment of water, waste water, sewage, or sludge; T - C14-23: Skins; hides; pelts; leather treatment; T - D06-23: Treatment of textiles or the like; laundering; flexible materials not otherwise provided for; T - E01-24: Environmental technology for the construction of roads, railways, or bridges; T - F01-24: Silencers; T - F23-24: Environmental combustion apparatus; combustion processes; T - F25-23: Liquefaction, solidification, or separation of gases or gaseous mixtures by pressure and cold treatment; T - F26: Drying; T - G01-24: Measuring radiation; T - H05-23: Electric techniques for chemical engineering; T - E01: Construction of roads, railways, or bridges; T - E02: Hydraulic engineering; foundations; soil-shifting; T - E03: Water supply; sewerage; T - E04: Building; T - E05: Locks; keys; window or door fittings; safes; T - E06: Doors, windows, shutters, or roller blinds, in general; ladders; T - E21: Earth or rock drilling; mining; T - B05-21: Applying liquids or other fluent materials to surfaces, in general; T - B22: Casting; powder metallurgy; T - B32: Layered products; T - B81: Micro-structural technology; T - B82: Nano-technology; T - C01: Inorganic chemistry; T - C03-20: Glass; mineral or slag wool; T - C04: Cements; concrete; artificial stone; ceramics; refractories; T - C21: Metallurgy of iron; T - C22: Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals; T - C23: Coating metallic material; coating material with metallic material; chemical surface treatment; diffusion treatment of metallic material; coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapour deposition, in general; inhibiting corrosion of metallic material or incrustation in general; T - C25: Electrolytic or electrophoretic processes; apparatus therefor; T - C30: Crystal growth; T - B60: Vehicles in general; T - B61: Railways; T - B62: Land vehicles for travelling otherwise than on rails; T - B63: Ships or other waterborne vessels; related equipment; T - B64: Aircraft; aviation; cosmonautics; T - F01-27: Machines or engines in general; engine plants in general; steam engines; T - F02: Combustion engines; hot-gas or combustion-product engine plants; T - F03: Machines or engines for liquids; wind, spring, or weight motors; producing mechanical power or a reactive propulsive thrust, not otherwise provided for; T - F04: Positive-displacement machines for liquids; pumps for liquids or elastic fluids; T - F15: Fluid-pressure actuators; hydraulics or pneumatics in general; T - F16: Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general; T - F17: Storing or distributing gases or liquids; T - F22: Steam generation; T - F23-27: Combustion engines; combustion processes; T - F23-30: Combustion apparatus; combustion processes; T - F24: Heating; ranges; ventilating; T - F25-30: Production of heat or cold by chemical reactions other than by combustion; T - F27: Furnaces; kilns; ovens; retorts; T - F28: Heat exchange in general; T - G05-31: Mechanical elements for controlling; regulating; T - G21: Nuclear physics; nuclear engineering; T - F21: Lighting; T - H01-1: Basic electric elements; T - H02: Generation, conversion, or distribution of electric power; T - H05-1: Electric techniques not otherwise provided for; T - G02: Optics; T - G03: Photography; cinematography; analogous techniques using waves other than optical waves; electrography; holography; T - H01-8: Basic electric elements for semiconductors; T - H01-9: Basic electric elements for optics; T - G06-6: Technology for computing; calculating; counting; T - G06-7: Methods for computing; calculating; counting; T - G08-3: Signalling - Telecommunications; T - G10-6: Speech or audio coding or decoding; T - G11-6: Information storage; T - G16-6: Information and communication technology [ICT] specially adapted for specific application fields; T - H01-3: Basic electric elements for telecommunications; T - H03: Basic electronic circuitry; T - H04-3: Electric telecommunication technique; T - H04-4: Electric digital communication technique; T - G09-2: Audio-visual technology for educating; cryptography; display; advertising; seals; T - G11-2: Audio-visual information storage; T - H04-2: Audio-visual electric communication technique; T - H05-2: Electric audio-visual techniques; P - SA: Manufacturing services on physical inputs owned by others; P - SE1: Construction services abroad; P - SE2: Construction services in the reporting economy; P - SB: Maintenance and repair services n.i.e.; P - SC1: Sea transport; P - SC2: Air transport; P - SC3: Other modes of transport; P - SC4: Postal and courier transport services; P - SDA: Business travel services; P - SDB: Personal travel services; P - SCB: Freight transport services (All modes of transport); P - SCA: Passenger transport services (All modes of transport); P - SCC: Other transport services (All modes of transport); P - SF: Insurance and pension services; P - SG: Financial services; P - SH: Charges for the use of intellectual property n.i.e.; P - SI1: Telecommunications services; P - SI2: Computer services; P - SI3: Information services; P - SJ1: Research and development services; P - SK1: Audiovisual and related services; P - SJ2: Professional and management consulting services; P - SJ3: Technical, trade-related, and other business services; P - SK2: Other personal, cultural, and recreational services.

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