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Abstract

Recent geopolitical challenges have revived the implementation of industrial and innovation policies. Ongoing discussions focus on supporting cutting-edge industries and strategic technologies but hardly pay attention to their impact on economic growth. In light of this, we discuss the design of innovation policies to address current development challenges while considering the complex nature of productive activities. Our approach conceives economic development and technological progress as a process of accumulation and diversification of knowledge. This process is limited by the tacit nature of knowledge and by countries' binding constraints to growth. Consequently, effective innovation policies should be place-based and multidimensional, leveraging countries' existing capabilities and addressing countries' current problems. This contrasts policies that lead to economic efficiencies, such as copying other countries' solutions to problems that countries do not currently have.

Keywords: innovation policy, industrial policy, economic complexity, know-how.

JEL Codes: O25, O30, O38, F60.

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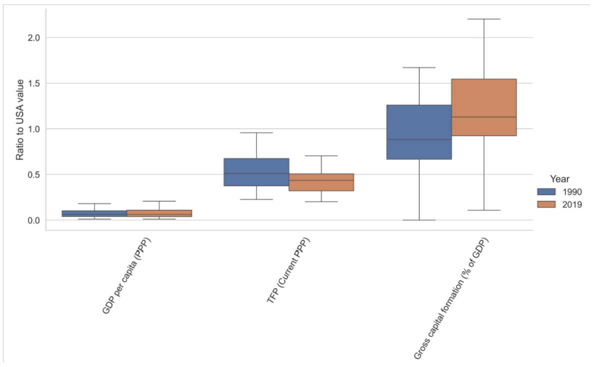
1 The puzzle of international development

Sustained growth differences between countries have led to vast income per capita differences. According to Maddison's database of historical income (Bolt & Van Zanden, 2020), when Adam Smith wrote the "Wealth of Nations" in 1776, the ratio between the highest and lowest income per capita was around 7 to 1. Currently, this ratio is more than 250. The historical roots of those significant income differences could be attributed to the Industrial Revolution, when the growth in the per capita income took off (Lucas, 2004). Although the timing and the scale of the income increases differ geographically (Galor, 2011), as well as the economies that undergo phases of income convergence and divergence (Pritchett, 1997; Patel et al., 2021), we still observe pronounced income inequalities.

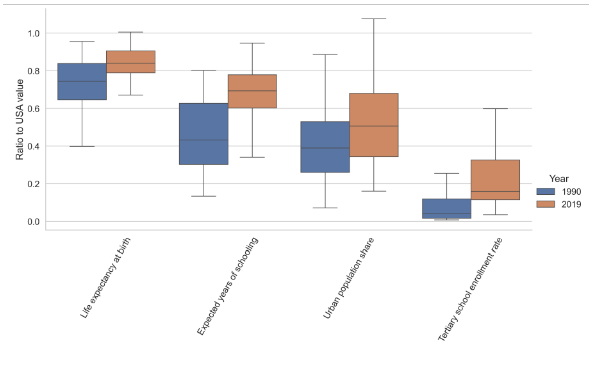
Economists posited that these income differences could be alleviated through improving in different dimensions, such as education, urbanization, greater labor force participation, capital accumulation, and life expectancy (Barro, 1996; Roser, 2014). Figure 1 shows the distribution of several of these measures relative to the US levels. The blue boxes represent the distribution of these ratios for 1990, and the orange boxes for 2019 (the latest available data consistently). We observe upward shifts in the distributions for life expectancy at birth, expected years of schooling, urban population share, tertiary school enrollment, and gross capital formation levels relative to the US. The fertility rate in developing countries shifted downwards in these countries as well. These promising developments, however, do not necessarily get reflected in convergence in GDP per capita or Total Factor Productivity (TFP).

Note that our unit of analysis is countries, which implies that we are giving equal weight to each country. Overall, income has grown in large countries such as China and India, translating into a decline in extreme poverty (Hasell et al., 2022). The lack of unconditional convergence in GDP per capita (see, e.g., Pritchett, 1997; Rodrik, 2013) has been challenged recently with evidence showing that there has been a slow convergence among countries (Patel et al., 2021). The lack of convergence in TFP could be also related to the measurement problems. Although TFP is used to compare countries or firms in terms of productivities (see, e.g., Acemoglu et al., 2023), it is a residual measure: TFP is determined as the portion of the income that is not explained by the factors of production (e.g., labor and capital).

Figure 1: Development indicators - Ratio of developing countries to US value



(a) Factors of production



(b) Development indicators

Source: Own construction, using data from the World Development Indicators (The World Bank, 2023), the UNDP HDR (UN Development Programme, 2023), and the Penn World Tables (Feenstra et al., 2015). This figure shows the distribution of country-level variables relative to the US levels for the years 1990 and 2019.

The lack of convergence in TFP could be attributed to the production factors in emerging economies not appearing as productive when compared to those in advanced economies.

Economists related income differences between countries to technological differences that make factors of production more productive. Solow (1956), for instance, argued that long-run economic growth could only be achieved through sustained technological development. Schumpeter (1942) and Aghion & Howitt (1992) emphasized the importance of creative destruction leading to technological progress by new technologies and industries replacing the old ones. Romer (1990) devised a theory of endogenous growth, in which the foundations of technology are "ideas" (knowledge) that increase with human capital and Research and Development (R&D) investments. Weitzman (1998) suggests that new ideas arise by recombining existing ones and that economic growth is constrained not by generating new ideas but by efficiently leveraging existing ones. Science and innovation policies have then become synonyms of economic development, as they can enhance the production and adoption of new "ideas" and, in turn, facilitate technological progress. Moreover, they have renewed hopes for narrowing the income gap and bringing sustained economic growth to more places.

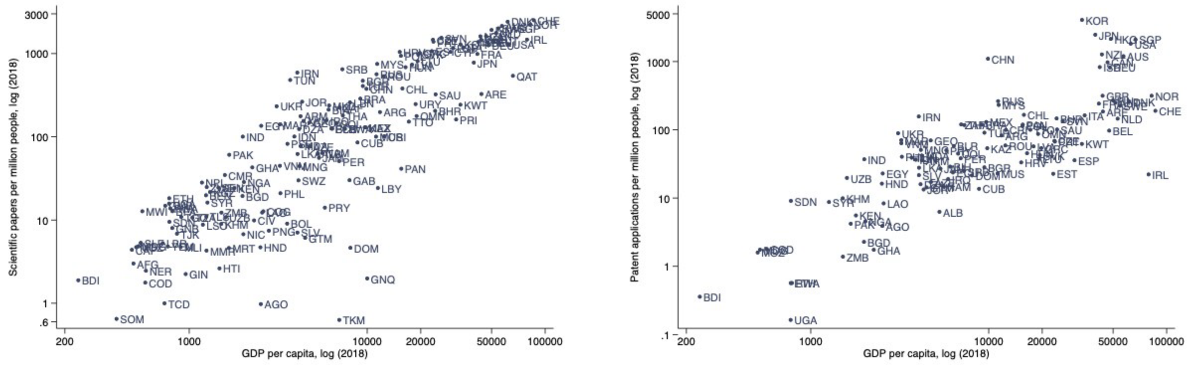
The challenges to advance science and innovation to boost economic growth are, however, far from being straightforward. Technological knowledge is an unconventional productive input that seems easy to copy and replicate but, in practice, barely moves in space (Maskell & Malmberg, 1999; Cohen & Levinthal, 1990). If ideas were easy to copy and replicate, lower-income countries would have an easier time catching up with advanced economies.[1] However, technology diffusion and adoption, as well as idea creation, have been remarkably uneven between countries. Measuring the idea-generating process can be proxied by looking at the production of scientific publications and patents. Figure 2a shows the relationship between scientific publications per capita and GDP per capita in 2018. Strikingly, the ratio of the highest per capita publication to the lowest observed value is nearly 4,000. Figure 2b shows a similar relationship between GDP per capita and patents per capita: the gap goes up to 25,000 (even when ignoring countries with 0 patents).

[1] According to Romer (1990), technologies are nonrival, partially excludable goods. They are nonrival, as once an idea is developed, others can find it easier to use it. However, their benefits are partially excludable, encouraging private agents to produce ideas. As shown in section 3, knowledge and ideas are sticky and concentrated in a few places.

Figure 2: Country Differences in Scientific Publications and Patenting

(a) Scientific Publications per capita

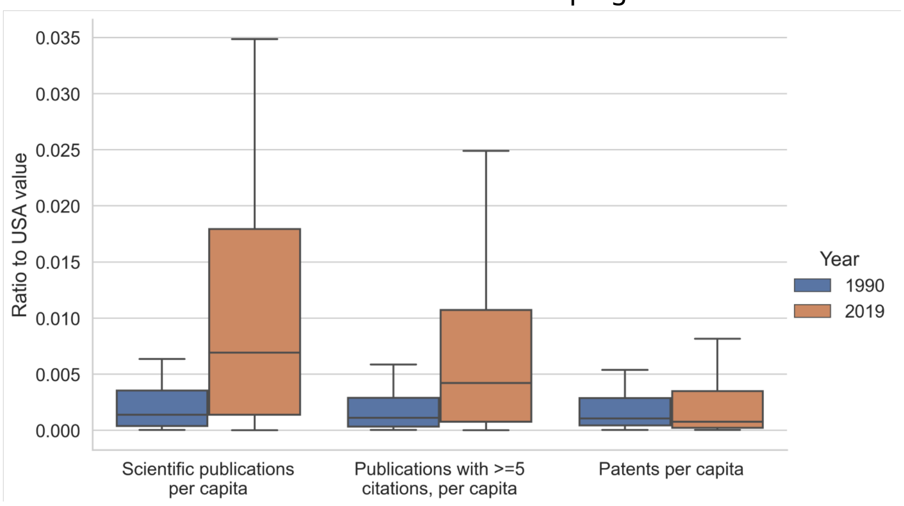
(b) Patenting per capita



Source: Own construction, using data from the World Development Indicators (The World Bank, 2023). Panel (a) shows scientific publications per capita versus GDP per capita for the year 2018. Panel (b) shows the patenting per capita.

Figure 3 shows the distribution of patents and scientific publications per capita relative to the levels of the USA for the years 1990 and 2019. We observe that the gap with the US has been closing in the scientific publications per capita, even after controlling for the quality of publications (i.e., by including only publications cited at least five times). However, this gap has been widening with the US in patenting. A possible explanation for this widening gap is the increase in the number of countries patenting, albeit with a lower intensity.

Figure 3: Innovation indicators - Ratio of developing countries to US value



Source: Own construction, using data from the World Development Indicators (The World Bank, 2023), OpenAlex (Priem et al., 2022), and PATSTAT. This figure shows the distribution of country-level variables relative to the US levels for the years 1990 and 2019.

What causes these significant gaps in ideas, income, and productivity? And what could be done to close this gap? This paper elaborates on these questions. We focus on how innovation policies can address current development challenges while considering the natural limits to knowledge creation and diffusion, as well as the complex nature of productive activities. We claim that effective innovation policies should be place-based and multidimensional, leveraging countries' existing capabilities and addressing countries' current problems. This contrasts policies that lead to economic efficiencies, such as copying other countries' solutions to problems that countries do not currently have.

The remainder of this paper comprises five additional sections. Section 2 highlights the historical flavors of industrial policy, covering the discrepancies, different policy goals, and instruments countries have adopted. Section 3 provides a theory of economic development and technological progress as a process of accumulation and diversification of knowledge based on the notion of economic complexity. Section 4 explains how technology diffuses, its main barriers, and how to overcome them. Section 5 shows how economic complexity approach can be used in industrial and innovation policy. Finally, section 6 concludes and addresses corresponding limitations and caveats.

2 Overview of approaches to industrial policy

Following Juhász et al. (2023), any government policy "that explicitly targets the transformation of the structure of economic activity in pursuit of some public goal" is considered to be an industrial policy. The goal could be wide-ranging, such as encouraging innovation, triggering economic growth, increasing productivity, enhancing know-how, creating jobs, promoting entrepreneurship, and preparing for climate events or natural disasters.

Industrial policy is often associated with "picking winners" by governments. Nevertheless, many economists have advocated against such policies and claimed the invisible hand of markets would self-direct agents toward industrialization. As Friedrich Hayek (1944) advocated, a government's function is to establish well-functioning markets: those that function as information aggregators, resource mobilizers, and places where individual agents respond to incentives. The process of governments picking winners could easily be distorted by inefficient politically connected players. Hence, it would be best to let the markets function.

Proponents of industrial policy highlight market failures (e.g., coordination problems - or positive externalities through learning by doing) as a justification for industrial policy (Hausmann & Rodrik, 2006; Hausmann, 2008; Harrison & Rodríguez-Clare, 2010; Juhász et al., 2023). As an example of coordination need, markets of electrical vehicles and markets for charging stations are linked to each other. On the other hand, so called infant industry argument states that an industry might need protection until it has brought down its costs by going through its learning curve. Sometimes these learning costs are internalized by industries but if the learning spills over to other industries or to the world, then industrial policies such as subsidies could have merit. Once industries concentrate in certain places, localization economies (Marshallian externalities) may develop over time as a result (Marshall, 1920; Krugman, 2009). Hence being located in specific places may incur competitive advantages for an industry that other places lack. As a result, what has been referred to as the 'window of locational opportunity' may close for industries over time (Boschma & Van der Knaap, 1999; Scott & Storper, 2003). Without protection, plants that set up activities new to a regions (e.g. pioneer plants which may diffuse knowledge from elsewhere, as we elaborate on later) may not survive as a result.

A complementary view points out that due their nature, public goods require backing of governments and their implementation could be addressed by industrial policies. The supply of public goods entails coordinating the actions of many public agencies, enacting legislation and backing of population which are not easily be left to invisible hands of the markets. Public goods have a different nature since often times they do not have prices as information signals nor they entail private motives. Public goods are critical inputs for many technologies to function. For example, driving a car need roads, traffic signs and road rules. Delivering electricity requires many things, such as standards and passing transmission lines through private lands, which could be addressed by governments. The inputs and public goods provided by governments are complements to the private inputs for production.

Some horizontal policies have world-wide prevalence. Almost all countries employ horizontal policies, such as R&D tax credits, apply to all firms and aim to increase productivity and innovation. But vertical policies that are industry or technology specific are scrutinized.

Historically, there have been many different flavors of industrial policy. In the 19th century, industrial policy was prevalent in many locations (see Juhász & Steinwender, 2024, for a recent review). In the second part of 20th century, there have been several influential ideas that shaped the utilization of industrial policy. For instance, around the time of the second world war, Rosenstein-Rodan (1943) proposed an industrial policy framework emphasizing the importance of *big push* towards industrialization by simultaneously promoting technologically related industries to reap the benefits of external economies of scope and scale. K. M. Murphy et al. (1989) formalized this framework, highlighting the challenges for single firms in unique sectors to create profits without having related counterparts (i.e. everything would be organized internally) - simultaneous industrialization of many related sectors, instead, can create profits. However, this approach assumes a correct identification of spillovers between industries and a high degree of coordination in their implementation. In this paper, we acknowledge the importance of spillovers or inter-dependencies between industries and argue that overcoming barriers to industrialization can be solved by exploiting inter-dependencies through successive addition of industries in a path-dependent manner.

Another influential approach implemented by many countries from the 1950s until the 1970s has been import substitution industrialization (ISI). The premise behind this approach is to provide a home market advantage to budding industries through import barriers so that those industries can build up a comparative advantage to be competitive in the future. ISI has been widely employed by many developing countries (Bruton, 1998), mainly in Latin America (Hirschman, 1968). Countries like Mexico and Brazil initially showed rapid industrialization under ISI, but later years showed exhaustion of growth (Alarcon & McKinley, 1992; Pineli & Narula, 2023). Similarly, Turkey also experienced a high level of industrialization and economic growth in the 1960s and early 70s under ISI, followed by a period of crisis in the late 70s (Pamuk, 1981). Interestingly, Bruton (1998, p. 919-920) summarizes what we learned from the ISI regime and states:

> The transfer of technological, administrative, and marketing knowledge was proving to be much more complex than was expected in the early 1950s. With fixed production coefficients and imported physical capital, it was difficult to understand why productivity could be lower in one country than another and why it would not grow equally fast in all countries. The term "infant industry" implied that simply getting older and larger would increase productivity, but this was not happening. [...] indigenous learning processes generally were not emerging in the import-substituting countries. The (implicit) assumption that simply changing the structure of an economy would also change its capacity to learn and accumulate knowledge was evidently incorrect. The task was much more complex.

Contrary to ISI, export-led growth aims to utilize international trade as an engine of growth and industrialization. East Asian miracles, such as Japan, South Korea, Singapore, and Hong Kong, have been at the forefront of adopting this approach (Gereffi & Wyman, 2014; Hauge, 2020). Export-led growth gave rise to rapid industrialization and subsequently elevated income levels. Hence, these countries experienced historically high growth rates in their GDP per capita. This experience, in turn, inspired the industrialization approaches of other Asian countries such as China, Thailand, Malaysia, Indonesia, and Vietnam.

Neo-liberal policies advocated during the 1980s, on the other hand, were focused on institutional deregulation and policies less focused on ’picking the winners’. In particular, the Washington Consensus (WC), summarized by John Williamson (1990), advocated that exports would increase and prosperity would follow if countries integrated into international capital markets with flexible exchange rates, reduced trade barriers, and controlled their inflation. Even though many countries followed this agenda promoted by many multilateral development and finance organizations, the results were lacking. Hence, such "one-size-fits-all" approaches lost their steam and were gradually replaced by context-dependent regional approaches.

For many countries, industrialization has been considered an escalator out of poverty. However, economists such as Dani Rodrik (2022) have argued that the success of export-led growth might not be replicable as the manufacturing industry becomes less labor-intensive over time. In the past, manufacturing industries created jobs that led to shared prosperity in countries. Currently, however, due to changes in the production processes, we observe premature industrialization leading to a higher share of service jobs in non-tradable industries resembling Baumol (1967) predictions of unbalanced growth.

In recent years, industrial policy has become more prominent in advanced economies (Juhász et al., 2023; Shih, 2023). The pressing issue of global climate change has pushed countries to encourage green transition. Correspondingly, the United States has adopted policies such as the Chip Act and the Inflation Reduction Act (IRA) - the latter incorporating substantial investments in climate change mitigation and energy security, making it a significant piece of climate change policy. The Act aims to reduce carbon emissions by approximately 40% by 2030 (compared to 2005 levels). Similarly, the NextGenerationEU Recovery Plan by the European Union has been created to finance the European Green Deal.

Differences between countries in addressing climate change and decarbonization efforts have also led to the enactment of progressive trade policies such as CBAM by the European Union. There are many provisions in these policies targeted towards specific sectors. For example, renewable energy tax credits such as 3 USD per kilogram for manufacturing solar-grade polysilicon or $12 per square meter for photovoltaic wafers under IRA are targeted specifically. Governments sometimes use industrial policies to incentivize firms to undertake risky investments or to invest in projects that would create externalities using instruments such as subsidies, grants, tax preferences, and tax credits. For example, the European Battery Alliance was launched by the European Commission, EU countries, industry, and the scientific community to make Europe a global leader in sustainable battery production and use and has raised more than 100 billion in investment commitments. Meanwhile, in the USA, IRA provides loan guarantees and credit subsidies for many clean energy projects. There are industrial policies targeted to promote consumer adaption of targeted products or services produced domestically. Tax credits for electric vehicles, installation of renewable energy sources, or guaranteed pricing of renewable power are aimed to for consumer adaptation. IRA has many provisions that incentivize consumers to adapt green industries as well.

The COVID-19 pandemic has revealed challenges associated with disruptions in global supply chains, such as semiconductor chip shortages leading to significant production bottlenecks in many industries across the globe. In conjunction with recent global political developments, countries increasingly pay attention to global value chains. For example, China's emergence and dominance in many sectors has been seen as a national security problem for the US, igniting trade wars between both countries. Similarly, Russia's invasion of Ukraine has led many countries to minimize their exposure to "non-friendly" countries. Ideas like "friend-shoring" to move global supply chains have been proposed to address the resiliency and dependability challenges of global supply chains.

Countries have also started enacting additional intellectual property (IP) protection measures. These have been put at the forefront of trade negotiations. Intellectual property rights allow inventors to monopolize the benefits of their ideas for a limited time. They may be barriers to the diffusion of ideas on the one hand, but on the other hand, they create incentives for people to capitalize on new ideas, accelerating growth in the process. For example, analyzing IP reforms undertaken by 16 countries, Branstetter et al. (2006) find that royalty payments for technology transferred to affiliates in these countries increase along with affiliate R&D expenditures and foreign patent applications.

Science & Innovation Policies

Science and Innovation policies can most often be thought of as industrial policies as well, as they are thought to be the accelerators of productivity growth. Many countries promote R&D efforts either through subsidies or tax breaks. Some advanced economies, like Japan, have introduced research consortia, which increased the productivity and patenting activity (Branstetter & Sakakibara, 1998, 2002). As to scientific progress, as shown in Figure 1, the countries increased their tertiary school enrollment rates accompanied by creating universities. The fruits of these efforts are reflected in an increase in publications: the median country increased the number of publications by 110% in ten years between the years 2008 and 2018.

Scientific and technological capabilities can translate into future industrial competitiveness and economic prosperity, but today's private incentives to develop them may be limited. The scientific and technological discoveries of today can ensure future industrial leadership, but the uncertainty of achieving successful outcomes and the impossibility of appropriating all knowledge rewards create major market failures (Arrow, 2015). From the point of view of private firms, the high uncertainty in the R&D outcomes may prevent their engagement in science and innovation activities, especially when they involve sizeable and long-term investments. Moreover, even when projects are successful, the non-rivalrous nature of knowledge (Romer, 1990) can produce positive externalities for their competitors, which may prevent them from investing in the first place. The market mechanism and the search for future rents may encourage firms to conduct some science and technology activities, but the amount may be suboptimal for society. To correct these primary failures, government interventions in science and technology are justified, although the most effective mechanisms should address differences in multiple dimensions, such as industry and firm size (Mezzanotti & Simcoe, 2023; Cohen et al., 2000; Levin et al., 1987; Fink & Raffo, 2019), type of innovation (Harabi, 1995), licensing level (Henkel, 2022), and the structure of licensing markets (Shapiro, 2000; Hagiu & Yoffie, 2013).

Government interventions in science and innovation can affect industrial policies. History has successful cases in which government initiatives have boosted the emergence of new industries (Gross & Sampat, 2023; Gruber & Johnson, 2019; Mazzucato, 2015). However, it is also full of examples in which government interventions in science and innovation have achieved adverse outcomes (Lerner, 2009; Mega, 2017). From the current empirical evidence, neither the extent to which science, innovation, and industrial policies should be connected nor the definition of priorities is always evident. Should science and innovation policies be subordinated to the existing local industries? Should they promote the emergence of new industries? Should they supply related or unrelated knowledge? The correct response varies based on location and contextual variables around each policy intervention. Trying to imitate best practices in successful policies fails to ensure their effectiveness in other places (Hospers, 2006; Jaruzelski, 2014; Breznitz, 2021).

Not all government interventions in science and innovation, however, should be considered as industrial policy. As claimed by Bonvillian (2022, p. 316), “industrial innovation policy involves governmental intervention in one or more of the post-research innovation stages, from development to prototyping to production, to further technology innovation.” Notice the focus on “post-research innovation stages.” New ideas become innovations when they materialize into products, but basic research and invention are often disconnected from production. Hence, industrial science and innovation policy is not only about creating more research or inventions, but about facilitating the translation of ideas into production.

Current policy interventions in science and innovation are also immersed in various tensions and opposite motivations. Most advanced economies prioritize the acquisition of strategic capabilities and the "control" of frontier technologies within their boundaries (e.g., the United States CHIPS and Science Act and Europe's NextGenerationEU Recovery Plan), neglecting the global spread of specialized resources and interactions required in frontier knowledge production (Miguelez et al., 2019; Crescenzi et al., 2019). Less advanced economies often try to replicate the successful measures adopted by frontier countries, disregarding their intrinsic characteristics and underestimating the flaws in the initial policy designs (Lerner, 2009). Within a country, R&D subsidies and investment tax credits may have a cross-sectoral extent, but different degrees of reliance on science and technology may imply industry-specific demands for science and innovation policy (Harabi, 1995; Mezzanotti & Simcoe, 2023; Fink & Raffo, 2019). Within an industry, science and innovation policy may focus on increasing innovation by supporting top firms, although a productive firm does not necessarily increase the productivity and social benefits for the whole economy (Rodrik, 2023).

Another set of concerns is related to the infrastructure required to implement industrial science and innovation policies. In other words, knowing which agents, connections, and infrastructure are needed to implement those policies and how to make them work as a system. As in the production of private goods, public policy and the provision of public goods is a complex, high-dimensional process involving hundreds of thousands of pages of legislation and hundreds of public agencies (Hausmann, 2008). The main concern with implementing industrial science and innovation policies is that, with a few exceptions, institutions are not designed to provide support in all innovation stages, in particular in post-research stages, or lack the practical experience to do it. For example, Bonvillian (2022) argues that in the US, the Department of Defense is the only institution that links basic and applied research, while the other agencies (e.g., the National Science Foundation, the Department of Energy, and the National Institutes of Health) rely on a disconnected system.

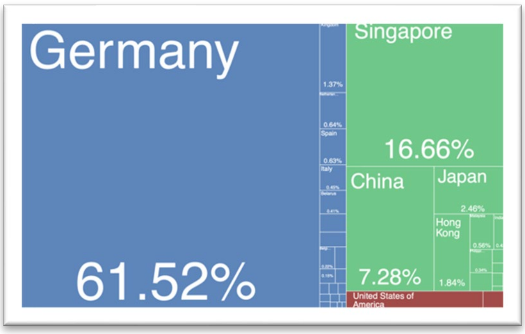
Given these challenges regarding industrial policies, the world has not experienced global and unconditional convergence in income levels. Therefore, to re-evaluate policy efforts in this light, in the next sections we elaborate on the nature of technology and barriers that limit its diffusion across the globe.

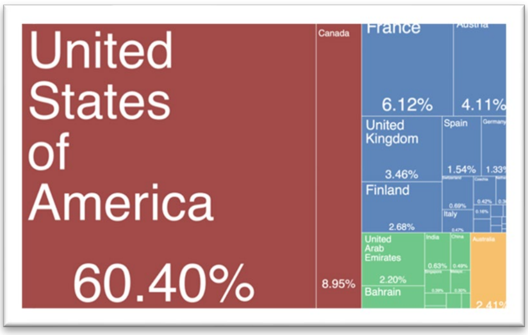
3 Knowledge and capabilities of places

Technology represents the knowledge that we harness to reshape our physical and social environments. It has grown tremendously over the past centuries, as illustrated by the increasing volumes of books, scientific papers, and patents. Yet our individual capacity to comprehend it remains static. Hence, we increasingly specialize as individuals and distribute knowledge across counterparts. Over time, such knowledge ends up in tools, machines, equipment, and so on (embodied knowledge). At the same time, we codify what we know and convert it into forms that can be shared through documentation, standardization, and classification (codified knowledge). Yet a large part of our knowledge is what Michael Polanyi called 'tacit,' which is much harder to codify: according to Gladwell (2008), it takes 10,000 hours of practice to become good at something.

The tacit component of knowledge implies that knowledge is stuck in brains and does not move freely across the world. It is 'sticky' and concentrated in certain places. This is why in 2021, for instance, Germany produced 61.52% of the world's stereoscopic microscopes and the United States 60.40% of the world's aircraft launching gears (Figure 4). Firms and workers in those industries are highly specialized and could hardly switch from producing microscopes to aircraft gears or vice-versa. This concentration and specialization of tacit knowledge can also be observed within industries. For instance, factories that make jet engines rarely make landing gear or communication devices. To put all these pieces together and produce a plane, somebody has to think about the design of each piece and how all of these pieces will come together. Hence, the growth of knowledge at the product level requires increasing the division of labor at the level of individuals.

Figure 4: Exporters of selected products in 2021





(a) Stereoscopic microscopes (b) Aircraft launching gears

Source: The Atlas of Economic Complexity (Harvard's Growth Lab, 2023).

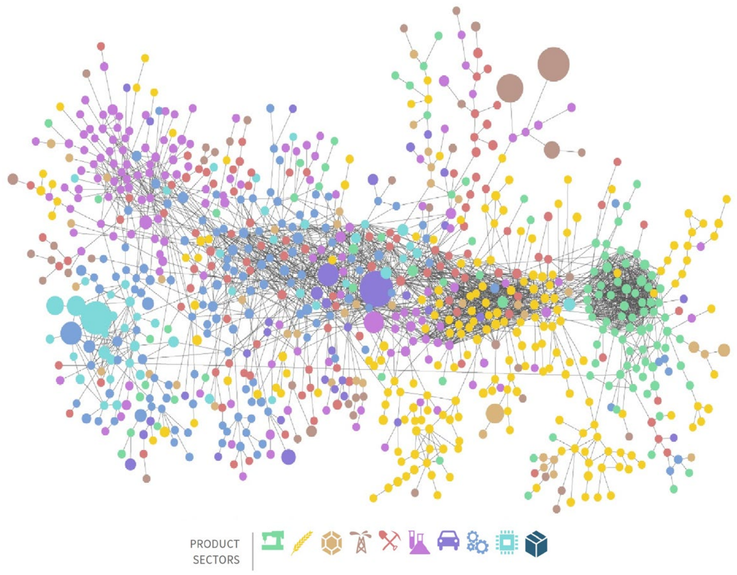
One metaphor to think about this is a game of **Scrabble** (in a separate paper adjunct to this one - Hausmann et al. (2024) - we formally define and measure this empirically). In this metaphor, products comprise a set of productive transformations of the world, which we can call letters. Words then represent the combination of these productive transformations that go into making a product. Not all combinations of letters are words. Some sets of letters are words, whereas other sets of letters are just gibberish. So products - the words - can be defined by the set of transformations needed to make them - the letters.

In this world description, we can think of **places as collections of words and letters, and products as collections of letters**. The relationship between a place and the letters it has can be regarded as the endowment of that place or the set of productive capabilities it holds. The relationship between the letters and the products they go into can be viewed as a matrix that explains the set of letters you need to make a specific product and in what order. A place, whether that be a city, state, or country, can be characterized by the letters it has and a product by the letters it requires.

Hidalgo et al. (2007) and Hausmann et al. (2014) formalize these logical statements about the world and empirically test them. Using international trade data, they find that the difference in the number of letters explains not only what products a place is likely to diversify info but also the pattern of diversification. This holds both for countries as well as for municipalities. They visualize this in what they call the **product space** (Figure 5), like a map of a forest. This forest is very irregular: there is no tree every five meters - instead, they are bunched together. A cluster of garment products is tightly clustered together, implying that the letters needed to make one kind of garment are very similar to the letters needed to make other kinds of garments. The same goes for machinery. Then, some poorly connected products suggest that those words were short: oil, for instance, which requires making holes in the ground, but there are very few products for which we need to build holes in the ground. By comparison, the letters to make a microwave oven are similar to those to make a washer or dryer.

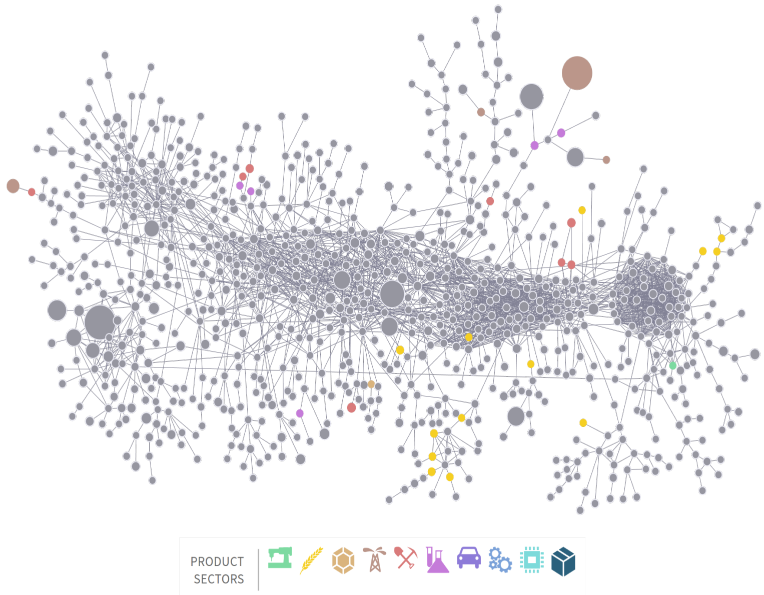
Countries, in turn, can be represented by their position in the product space. How many metaphorical monkeys does a country have to jump to other branches of this forest and diversify into new products? Venezuela, for instance, has very few monkeys and almost all in very peripheral positions such as oil and raw materials (Figure 6). Mexico, on the other hand, has many more monkeys, whereas Austria, despite being less than a tenth the size of Mexico, is highly diversified, with monkeys everywhere in the product space. This implies that countries can move easily to nearer activities than those further away. In Hausmann et al. (2024), we measure this for each country in different dimensions (e.g., trade and patents).

Figure 5: Product space



Source: The Atlas of Economic Complexity (Harvard's Growth Lab, 2023). Note: Nodes (dots) represent products (following the Harmonized System - HS - 1992 classification) and links (lines) their primary connections. Products that are strongly related to one another (i.e., requiring related capabilities) are clustered closer together in the network. Node sizes are based on the product's world trade. Node colors represent the product's major sectors: textiles, agriculture, stone, minerals, metals, chemicals, vehicles, machinery, electronics, and others.

Figure 6: Venezuela's exports in the product space, in 2021



Source: The Atlas of Economic Complexity (Harvard's Growth Lab, 2023). Note: Only the products for which Venezuela has a revealed comparative advantage are colored. See figure 5 for a description of the main elements of the product space.

This finding has since been tested in many different settings and is now called the **principle of relatedness** (Hidalgo et al., 2018; Hausmann et al., 2022; Li & Neffke, 2023): the process of diversification tends to favor activities that are more closely related to each other. Neffke & Henning (2013), for instance, applied this logic to job transitions where every tree is an occupation and a monkey is a person, and the question is how do people move between jobs? People tend to move to jobs that have similar skill requirements.

This model allows one to test many implications for the economy. First, the more letters you have, the more words you can put together. The **diversity** of letters maps into a diversity of words that you can put together. Second, the longer the word, the harder it is to make it. If you assume that there is some distribution of letters among places, the longer the word, the fewer the places that can make it. We call the number of places that can make a product the **ubiquity** of the product. So, with a short word, you would expect something that can more or less be made anywhere, whereas a longer word would be more challenging. It is also logical to assume that a place with more letters should be able to make more words and longer words. A place that has a lot of letters should be more diversified and specialized in less ubiquitous products, and these products themselves should be made by diversified countries. This iterative process creates an index of knowledge intensity and the completeness of the letter space, which is called the economic complexity index (ECI) proposed in Hidalgo & Hausmann (2009) and formalized in Hausmann et al. (2014).

The economic complexity index is highly correlated with GDP and income per capita. Poor countries have few letters, whereas rich countries have a lot of letters. More importantly, if relative to other countries with the same GDP or income per capita, a country has fewer letters, it would tend to grow more slowly, whereas if it had more letters, it would tend to grow faster. In some sense, this space of letters was more fundamental than the current income level. Here, the only information used to calculate the index is which goods the locations are making and which other countries are making these. This gave us confidence that we were finding something more fundamental about how growth had something to do with expanding a set of capabilities that a country had, a filling up of the fraction of the entire alphabet. The more letters a country had, the more words it could make, and in that process, it would become not only more diverse but also able to make less ubiquitous words. This gave us an intuition of how distributed knowledge in a society relates to growth and income.

Hence, the world is explained in ways other than being made out of physical capital, human capital, and labor as fundamental essences, but instead of different letters, much like how chemistry is made of different atoms. This allows for a richness in understanding the nature of production and growth that emphasizes the different dimensions of knowledge and how distributive knowledge needs to come together to make things. This mimics Lucas (1993), who argues that growth fundamentally depends on learning by doing, but this process peters out within existing industries. To sustain growth, countries need to move to new industries where they can benefit from new learning-by-doing rounds. However, the growth opportunities for the advanced economies are also scarce;

as Bloom et al. (2020) document, ideas leading to exponential growth are becoming harder to find.

4 The diffusion of knowledge and overcoming its barriers

A key question is how a country can acquire new letters to make new words and diversify into new activities, particularly towards the denser part of the product space where more complex products are located. They would need the knowledge to make such jumps. According to the economic complexity view, the secret of economic development is productive knowledge. Productive knowledge is distributed in different heads, tools, and materials, and the process of economic growth entails its accumulation and its expression in more goods. There is a more diverse set of goods and more complex goods. In the Scrabble world, this corresponds to more letters, more words, and longer words. This suggests that development goes with diversification, which is the opposite of specialization. In reality, diversification and specialization are two sides of the same coin, seen from two different vantage points, and go hand in hand. If individuals specialize, then the place in which those individuals live will have diversified. Specialization at the lower level, therefore, implies diversification at the higher level. Hence, one implication of this theory is the importance of tacit knowledge embedded in specialized individuals is crucial for diversification. Yet the tacitness of knowledge implies that knowledge does not move freely across the world. Hence, countries may lack the knowledge to make jumps into new activities. How can this barrier possibly be overcome?

Diversification is fundamentally a chicken-and-egg problem. For a place to diversify into new activities, it must learn to do things that it has not been able to do in the past. But how does a place begin to do things if they do not know how to make things they have not made? Watchmakers are needed to make watches, yet places that do not have watchmakers do not make watches. And how do you become an experienced watchmaker in a place that does not make watches? Having a missing letter is bound to be difficult.

Having four missing letters is yet more challenging. It is like having four chicken and egg problems to solve simultaneously.

At the same time, countries benefit from a high level of basic skills to be able to absorb more complex and specialized capabilities from elsewhere Hanushek & Woessmann (2015). Nevertheless, the accumulation of basic skills is not devoid of the chicken-and-egg-problem described above. In a location where most of the industries present do not use high-skill or specialized labor, the incentives to groom these skills by individuals or parents would be absent. Once the population foresees the possibilities and prospects opening up with high skills, the incentives the build higher quality education would emerge. In the complexity framework, we can think of the letters as being likely shaped by the education system. But if the letter has no word to be used in, the letters will not emerge.

The complexity framework we develop here is line with the criticism by Jones (2014a) how human capital stock is accounted for. In particular, Jones (2014a) highlights the importance of human capital skills that are not perfectly substitutable with each other. This view is similar to the capability approach if we assume some of the capabilities, or letters in the Scrabble metaphor, correspond to human skills. Jones (2014b) in this regard speaks of the 'Knowledge Trap' that developing countries may find themselves stuck in. It is a challenge for developing countries to acquire specialist skills as such because a complementary ecosystem of skills is lacking. Individual letters require the presence of other letters to make words. A heart surgeon, for instance, requires at least an anesthesiologist to operate effectively - without one, the surgeon's value would greatly decrease. Complex activities often require complementary capabilities for individual specialist capabilities to become meaningful. This division of labor allows for the existence of collective know-how, which is greater than the sum of individual skills.

As a result, for instance, when it comes to education policy, it is not enough for an education system to produce skilled individuals as such. This may be a necessary condition to absorb complex knowledge from elsewhere (Hanushek & Woessmann, 2015) but, at the same time, it is not a sufficient condition to overcome the knowledge trap. Neffke (2017) finds that, because specialist workers with similar skills are substitutable, a significant increase in co-worker substitutability is associated with 4.8% lower wages. A similar increase in complementarity, however, results in 18.1% higher wages. Hence, whole skill ecosystems accounting for missing letters - need to be developed for specialist skills to become valuable.

How can this challenge of missing letters be overcome? The presence of major organizations with diversified portfolios is one way, allowing for internal diffusion and redeployment of capabilities. Particularly relevant here are those with significant resources - such as conglomerates - that can re-deploy not just existing letters (e.g. workers) but also whole teams towards new - and often related - activities. Famous examples of such internal diversification are the *keiretsus* of Japan and the *chaebols* of South Korea, which - in alliances with the government that promoted institutions to foster the diffusion of capabilities (Naughton & Segal, 2003) - propelled growth and diversification of both countries into new technological activities (Saxenian, 2006). For many regions, however, a significant diversified industrial base is not yet present.

Relatedly, Hausmann & Neffke (2019) analyzed the diversification patterns in the context of Eastern Germany, which has experienced a gradual revival of its industrial sector after initially losing 60% of its manufacturing jobs following German reunification. The migration of workers from west to east played a crucial role in this process. The first plants in a local industry - the **pioneer plants** - in eastern Germany heavily relied on experienced workers from western regions, hiring a significantly larger proportion of college-educated workers with industry experience from the West than the East. The pioneer plants address the shortage of local workers with industry experience by employing fewer highly skilled workers and workers with specialized skills than plants in industry clusters. Furthermore, a pioneer may train workers that are then hired by followers, meaning that the discovery process may not be adequately incentivized (Hausmann & Rodrik, 2003). Other new industries with similar know-how requirements may even hire them. Hence, learning by doing can also generate positive spillovers. Hausmann & Neffke (2019) also find that despite recruiting many well-paid workers from outside the region, they still generate substantial employment opportunities for local workers and individuals entering or re-entering the job market.

In fostering the migration of workers from elsewhere, such pioneer plants also tend to be the most likely agents of the structural transformation of economies. Neffke et al. (2018) find that the longest jumps in the forest are done by entrepreneurs and existing firms from elsewhere that set up new plants in regions. The activities they set up are much better embedded in regions where the founders originate from: they thus foster a process of knowledge diffusion across regions. In a period of 17 years of structural transformation in regions in Sweden, those agents are most likely to survive and thrive. In contrast, existing firms that try to jump into new activities are more likely to fail. As Neffke et al. (2018) use labor flows to measure the extent to which industries rely on similar capabilities (relatedness) - rather than the co-occurrence of products entities such as in Hidalgo et al. (2007) - their analysis includes services as well.

First entrants in a local industry, in turn, may set off a snowball process that fosters further clustering of the industry in the region. Localization economies - local-specific advantages specific to the industry - may develop over time. De Vaan et al. (2013) analyze the emergence and spatial evolution of the video games industry over time between 1972 and 2007, finding that the net effect of clustering becomes positive after a cluster reaches a critical size. Morrison & Boschma (2019) find similar results for the motorcycle industry.

Hence, for countries to achieve structural transformation, it may be essential to attract companies and workers from elsewhere. Annalee Saxenian (2006) calls these the New Argonauts: foreign-born, highly-skilled workers who venture back and forth between Silicon Valley and their home countries, infusing the latter with new knowledge in the process. She finds this process crucial to emerging innovation hotbeds worldwide, such as the Hsinchu-Taipei corridor. It is, in fact, reflected in trade patterns across the world. Bahar & Rapoport (2018) find that a 10% increase in immigration from exporters of a given product (particularly high-skilled workers) leads to a 2% increase in the probability that the host country starts exporting that good from scratch in the next ten years.

A particular diffusion channel in this regard, particularly of labor mobility, is multinational companies. Crescenzi et al. (2022) find that when such companies set up foreign R&D activities in regions, those regions climb fourteen centiles in global innovation ranks. Foreign Direct Investment (FDI) can thus be a key stepping stone to acquiring new letters. Indeed, at the regional aggregate, Elekes et al. (2019) find that most structural change is induced not by domestic firms but rather by foreign-owned firms.

Other channels of knowledge diffusion, in addition to FDI and migration, are diaspora networks. Hausmann (2015) calls these 'Diaspora Goldmines': the opportunity for countries to tap into the knowledge of native residents that live abroad. The origins and growth of the IT industry in China, India, and Israel can be traced back to professional connections between domestic engineers and diaspora engineers and entrepreneurs in the Silicon Valley that developed during the last three to four decades (Smart & Hsu, 2004; Saxenian, 2006; Pandey et al., 2006). Similarly, the recent modernization of agriculture in Albania and its growth in exports of agricultural products can be traced back to return migrants from Greece and Italy, who brought about advanced technological know-how in the sector (Hausmann & Nedelkoska, 2018). Moreover, part of the manufacturing diversification of rural China can be traced back to Chinese migrants who acquired production skills in the urban parts of China (R. Murphy, 1999; Démurger & Xu, 2011). Hence, in the development context, it is essential for countries to gain deeper insights into their diaspora populations. One example of this is Nedelkoska et al. (2021), who study the geography and background of 1.7 million members of the global Colombian diaspora. They suggest that engaging the Colombian diaspora while being abroad can be the most effective strategy to boost economic development.

All these mechanisms are examples of **moving brains** rather than moving knowledge across brains. The latter, moving knowledge into brains, is much harder to accomplish given the tacitness of knowledge. Illustrative in this respect is business travel, which, despite modern communication, is still very prevalent and essential for development. Coscia et al. (2020) find that business travel networks predict which new economic activities will develop in a country and, inversely, which old activities will be abandoned. Particularly, business travel from countries specializing in a specific industry causes growth in that economic activity in the destination country. In fact, they find that in statistical terms, this effect has the most substantial impact on a range of bilateral relationships between countries, such as foreign direct investment, trade, and migration.

Expertise is thus housed in people's minds, highlighting the importance for countries to draw in human capital rather than setting up obstacles to skilled immigration. Countries can leverage their diasporas, encourage foreign direct investment in novel sectors, and be open to the immigration of skilled workers and the acquisition of foreign companies.

5 Economic Complexity in Industrial and Innovation Policy

The economic complexity framework can shed some light on how to address these different motivations by conceiving industrial, science, and innovation policies as part of a process of knowledge diversification. Under the economic complexity framework, the final goal of policy interventions is to maximize economic development by diversifying the set of capabilities (letters) so that economies can create more complex products (longer words). It acknowledges the role of the existing capabilities available in a territory, as knowledge diversification is embedded in a path-dependence process, in which the current knowledge can limit the possibilities to develop new technologies (Hidalgo et al., 2018). However, the role of policy interventions is to help economies identify and develop the capabilities that generate the most binding constraints to growth (Hausmann et al., 2008), even if they are not part of the adjacent set of opportunities or differ from the natural path dependence process. In this way, economies can modify their fate and escape from the traps imposed by their existing set of capabilities (Balland et al., 2019).

The economic complexity framework requires thinking about transversal policy objectives and designing the learning mechanisms that solve the most binding constraints to growth. Under this approach, coordination of science, innovation, and industrial policy is required to develop the letters (capabilities) that would allow the creation of longer words (more complex products). Considering the rules that govern know-how, which require concentration of activities, and the financial limitations, which determine the bandwidth of simultaneous interventions, countries should design tailored solutions to address the most pressing binding constraints by groups of productive activities. This requires the coordination of actors and institutions from multiple domains but who are part of a limited space and share some common general interests. Moreover, it involves the creation of mechanisms that can identify the most binding constraints, correct them, and learn from the difficulties found in previous interventions. Isolated interventions or copying solutions to problems they do not have is less effective than developing the mechanisms to produce local know-how to correct their own binding constraints.

Figure 7: Attractiveness and Feasibility

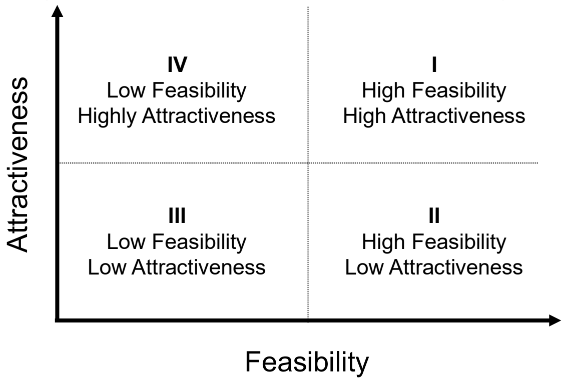


Figure 7 illustrates a framework where the economic complexity approach could be applied in the design of industrial or innovation policy. Two axes in the figure show the attractiveness and feasibility of innovation domains such as industries, technology classes, or scientific fields in a given location. Feasibility captures the capability or know-how overlap between the location and the innovation field of interest and is calculated by the share of proximities that are present in the location for the field. This measure is often captured by the relatedness density (Hidalgo et al., 2018). The second axis, attractiveness, could stem from many attributes, such as the complexity of the field or the growth of the field. In the smart specialization approaches, for instance, complexity metrics are often used (Balland et al., 2019). But another attractiveness feature that could be utilized is the complexity outlook gain (COG) measure (Hausmann et al., 2014), which captures how much an innovation field brings other high-complexity entities closer to the location's capability base. We can think of attractiveness measures like PCI and growth as a one-step ahead feature, whereas COG addresses a two-steps-ahead dimension because it is about how much closer all other fields become closer.

An industry, a technology class, or a scientific field that a location is not active in would fall into one of the four quadrants in Figure 7. If an entity falls into the first quadrant, it is both highly attractive and feasible. Hence, we expect these industries to appear in the location without in need of much intervention. The second quadrant consists of innovation fields that are feasible but not highly attractive. Generally, locations do not employ industrial or innovation policy to address the fields in this quadrant. The third quadrant has both low attractiveness and low feasibility. This quadrant is not also a part of desirable sets of the innovation policies. The fourth quadrant, on the other hand, harbors the innovation fields that are highly attractive but not feasible. Especially for many emerging market economies, many attractive innovation fields fall into this quadrant. In combination with the absence of many opportunities absent in the first quadrant, the locations need to utilize the break the vicious cycle.

In addition to its prognostic usage, the framework captured in Figure 7 could also be used for diagnostic purposes. In particular, by analyzing the attractiveness-feasibility map of a location in previous years, a policymaker could identify innovation fields that were both feasible and attractive in the previous years but not yet appeared in the location. With this tool in hand, the policymaker could identify market failures that impeded the diversification process. For example, for an innovation field that was in the first quadrant but had not appeared yet, the policymaker could gather information from other innovation fields that share capabilities with the field of interest to uncover where the market failures are and address them through industrial or innovation policy.

The economic complexity methodology described here also comes with some limitations. First, implicitly, we assume that the same technologies are used globally to make a product. However, there might be differences in capability requirements in different modes of production. Second, all products within an industry or all patents within a technology class are considered homogeneous. Nevertheless, there might be quality differences. These quality differences could stem from differential know-how utilization as well. Third, we assume that the countries make products, patent in a technology class, or publish in a scientific field if they have all the necessary know-how to do so. However, the opposite might not be true: Countries might possess all the required know-how but choose not to be active in a field for various reasons, such as insufficient demand or limited resources in rivalrous capabilities. While building complexity metrics, we give equal weights to making and not making a product.

Fourth, traditional trade models (e.g., the Ricardian model or the Heckscher–Ohlin model) would result in specialization patterns, but the complexity model posits that diversification is the dominant strategy for sustainable growth. Imbs & Wacziarg (2003) claim that the stages of development first follow a diversification pattern but later turn into specialization. Bahar et al. (2023) recently challenged this view and showed that diversification remains the dominant strategy even at higher income levels.

6 Conclusions

This paper emphasizes the importance of structural transformation for countries to develop. In the long run, economies depend on their ability to develop new activities to offset destruction and decline in other parts of their economies. Such renewal was already emphasized in the 1950s and 1960s in early development economics by Lewis (1955), Rostow (1960), Kuznets (1966) and Kaldor (1967) and follows (Schumpeter, 1942) who identified this process of creative destruction as the driving force behind economic development. It is key to, for instance, the European Union's smart specialization agenda on regional development, which outlines that "smart specialization seeks robust and transparent means for nominating those new activities, at a regional level, that aims at exploring and discovering new technological and market opportunities and at opening thereby new domains for constructing regional competitive advantages." (Foray & Goenaga, 2013, p. 1). In this light, this paper introduced the economic complexity framework, which views regions and countries as portfolios of capabilities and spaces in different dimensions (products, technologies, science) as tools for policymakers to identify potential paths for diversification and transformation by introducing new but related capabilities. In doing so, this paper highlights mechanisms that facilitate this - such as migration and foreign direct investment - that diffuse capabilities across space, which policy could focus on.

Throughout this paper, we focused on location based industrial policy. However, some current challenges like climate change need to be addressed globally. It is also important current trade-offs may require switching restrictive local goals to a more globally-minded approach to industrial policy, where each element in a value chain is located where it makes sense to put it to maximize the shared value, and economies claim as much as they can (Hausmann & Ahuja, 2023).

This paper argues that industrial and innovation policies must consider the path dependency driven by underlying capabilities and know-how. In the accompanying paper, we will show how the implications of these capabilities could be captured by economic complexity methods that would enable us to measure the extent of capabilities present in a country and show us the adjacent possible.

References

Acemoglu, D., Autor, D., & Patterson, C. (2023). *Bottlenecks: Sectoral imbalances and the us productivity slowdown* (Working Paper No. 31427). Cambridge, MA, USA: National Bureau of Economic Research.

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, *60*(2), 323–351.

Alarcon, D., & McKinley, T. (1992). Beyond import substitution: The restructuring projects of Brazil and Mexico. *Latin American Perspectives*, *19*(2), 72–87.

Arrow, K. J. (2015). Economic welfare and the allocation of resources for invention. In *The rate and direction of inventive activity* (pp. 609–626). Princeton: Princeton University Press.

Bahar, D., Bustos, S., & Yildirim, M. A. (2023). *Stages of development revisited.* (in preparation for World Development Report, 2024)

Bahar, D., & Rapoport, H. (2018). Migration, knowledge diffusion and the comparative advantage of nations. *The Economic Journal*, *128*(612), F273–F305.

Balland, P.-A., Boschma, R., Crespo, J., & Rigby, D. L. (2019). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional studies*, *53*(9), 1252–1268.

Barro, R. J. (1996). *Determinants of economic growth: A cross-country empirical study* (Working Paper No. 5698). Cambridge, MA, USA: National Bureau of Economic Research.

Baumol, W. J. (1967). Macroeconomics of unbalanced growth: the anatomy of urban crisis. *The American economic review*, *57*(3), 415–426.

Bloom, N., Jones, C. I., Van Reenen, J., & Webb, M. (2020). Are ideas getting harder to find? *American Economic Review*, *110*(4), 1104–1144.

Bolt, J., & Van Zanden, J. L. (2020). *Maddison style estimates of the evolution of the world economy. a new 2020 update* (Maddison-Project Working Paper No. WP-15). Groningen, The Netherlands: University of Groningen.

Bonvillian, W. B. (2022). Industrial innovation policy in the united states. *Annals of Science and Technology Policy*, *6*(4), 315–411.

Boschma, R., & Van der Knaap, G. (1999). New high-tech industries and windows of locational opportunity: the role oflabour markets and knowledge institutions during the industrial era. *Geografiska Annaler: Series B, Human Geography*, *81*(2), 73–89.

Branstetter, L. G., Fisman, R., & Foley, C. F. (2006). Do stronger intellectual property rights increase international technology transfer? empirical evidence from us firm-level panel data. *The Quarterly Journal of Economics*, *121*(1), 321–349.

Branstetter, L. G., & Sakakibara, M. (1998). Japanese research consortia: a microeconometric analysis of industrial policy. *The Journal of Industrial Economics*, *46*(2), 207–233.

Branstetter, L. G., & Sakakibara, M. (2002). When do research consortia work well and why? evidence from japanese panel data. *American Economic Review*, *92*(1), 143–159.

Breznitz, D. (2021). *Innovation in real places: Strategies for prosperity in an unforgiving world*. Oxford University Press, USA.

Bruton, H. J. (1998). A reconsideration of import substitution. *Journal of Economic Literature*, *36*(2), 903–936.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 128–152.

Cohen, W. M., Nelson, R., & Walsh, J. P. (2000). *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* (Working Paper No. 7552). Cambridge, MA, USA: National Bureau of Economic Research.

Coscia, M., Neffke, F. M., & Hausmann, R. (2020). Knowledge diffusion in the network of international business travel. *Nature Human Behaviour*, *4*(10), 1011–1020.

Crescenzi, R., Dyèvre, A., & Neffke, F. (2022). Innovation catalysts: how multinationals reshape the global geography of innovation. *Economic Geography*, *98*(3), 199–227.

Crescenzi, R., Iammarino, S., Ioramashvili, C., Rodríguez-Pose, A., & Storper, M. (2019). The geography of innovation: local hotspots and global innovation networks. *World Intellectual Property Organization (WIPO) Economic Research Working Paper Series*(57).

Démurger, S., & Xu, H. (2011). Return migrants: The rise of new entrepreneurs in rural China. *World Development*, *39*(10), 1847–1861.

De Vaan, M., Boschma, R., & Frenken, K. (2013). Clustering and firm performance in projectbased industries: the case of the global video game industry, 1972–2007. *Journal of Economic Geography*, *13*(6), 965–991.

Elekes, Z., Boschma, R., & Lengyel, B. (2019). Foreign-owned firms as agents of structural change in regions. *Regional Studies*, *53*(11), 1603–1613.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150–3182.

Fink, C., & Raffo, J. (2019). What role for intellectual property in industrial development? *Intellectual Property and Development: Understanding the Interfaces: Liber amicorum Pedro Roffe*, 119–136.

Foray, D., & Goenaga, X. (2013). The goals of smart specialisation. *S3 policy brief series*, *1*, S3.

Galor, O. (2011). *Unified growth theory*. Princeton University Press.

Gereffi, G., & Wyman, D. L. (2014). *Manufacturing miracles: paths of industrialization in Latin America and East Asia* (Vol. 1189). Princeton University Press.

Gladwell, M. (2008). *Outliers: The story of success*. Little, Brown.

Gross, D. P., & Sampat, B. N. (2023). *America, Jump-started: World War II R&D and the Takeoff of the US Innovation System*. National Bureau of Economic Research.

Gruber, J., & Johnson, S. (2019). *Jump-starting america: How breakthrough science can revive economic growth and the american dream*. Hachette UK.

Hagiu, A., & Yoffie, D. B. (2013). The new patent intermediaries: platforms, defensive aggregators, and super-aggregators. *Journal of Economic Perspectives*, *27*(1), 45–66.

Hanushek, E. A., & Woessmann, L. (2015). *The knowledge capital of nations: Education and the economics of growth*. Cambridge, MA, USA: MIT Press.

Harabi, N. (1995). Appropriability of technical innovations an empirical analysis. *Research Policy*, *24*(6), 981–992.

Harrison, A., & Rodríguez-Clare, A. (2010). Trade, foreign investment, and industrial policy for developing countries. *Handbook of Development Economics*, *5*, 4039–4214.

Harvard's Growth Lab. (2023). *The Atlas of Economic Complexity.* Retrieved 2023-09-26, from https://atlas.cid.harvard.edu/

Hasell, J., Roser, M., Ortiz-Ospina, E., & Arriagada, P. (2022). Poverty. *Our World in Data*. (https://ourworldindata.org/poverty)

Hauge, J. (2020). Industrial policy in the era of global value chains: Towards a developmentalist framework drawing on the industrialisation experiences of south korea and taiwan. *The World Economy*, *43*(8), 2070–2092.

Hausmann, R. (2008). *The other hand: high bandwidth development policy* (Working Paper No. RWP08-060). Cambridge, MA, USA: Harvard Kennedy School.

Hausmann, R. (2015). The diaspora goldmine. *Project Syndicate–The World's Opinion Page*, *25*.

Hausmann, R., & Ahuja, K. (2023). A more globally-minded European green industrial policy. In S. Tagliapietra & R. Veugelers (Eds.), *Sparking Europe's new industrial revolution: A policy for net zero, growth and resilience* (p. 152-164). Bruegel.

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., Simoes, A., & Yıldırım, M. A. (2014). *The atlas of economic complexity: Mapping paths to prosperity*. The MIT Press.

Hausmann, R., & Nedelkoska, L. (2018). Welcome home in a crisis: Effects of return migration on the non-migrants' wages and employment. *European Economic Review*, *101*, 101–132.

Hausmann, R., & Neffke, F. M. (2019). The workforce of pioneer plants: The role of worker mobility in the diffusion of industries. *Research Policy*, *48*(3), 628–648.

Hausmann, R., & Rodrik, D. (2003). Economic development as self-discovery. *Journal of development Economics*, *72*(2), 603–633.

Hausmann, R., & Rodrik, D. (2006). Doomed to choose: industrial policy as predicament. *John F. Kennedy School of Government, Harvard University*, *9*.

Hausmann, R., Rodrik, D., & Velasco, A. (2008). Growth diagnostics. *The Washington consensus reconsidered: Towards a new global governance*, *2008*, 324–355.

Hausmann, R., Stock, D. P., & Yıldırım, M. A. (2022). Implied comparative advantage. *Research Policy*, *51*(8), 104143.

Hausmann, R., Yildirim, M. A., Chacua, C., Hartog, M., & Matha, S. G. (2024). Global trends in innovation patterns: A complexity approach. *WIPO Economic Research Working Paper*(TO BE CONFIRMED).

Hayek, F. A. (1944). *The road to serfdom*. Chicago, IL: University of Chicago Press.

Henkel, J. (2022). Licensing standard-essential patents in the IoT – A value chain perspective on the markets for technology. *Research policy*, *51*(10), 104600.

Hidalgo, C. A., Balland, P.-A., Boschma, R., Delgado, M., Feldman, M., Frenken, K., … others (2018). The principle of relatedness. In *Unifying themes in complex systems ix: Proceedings of the ninth international conference on complex systems 9* (pp. 451–457).

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*, *106*(26), 10570–10575.

Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, *317*(5837), 482–487.

Hirschman, A. O. (1968). The political economy of import-substituting industrialization in Latin America. *The Quarterly Journal of Economics*, *82*(1), 1–32.

Hospers, G.-J. (2006). Silicon somewhere? assessing the usefulness of best practices in regional policy. *Policy studies*, *27*(1), 1–15.

Imbs, J., & Wacziarg, R. (2003). Stages of diversification. *American Economic Review*, *93*(1), 63–86.

Jaruzelski, B. (2014). Why Silicon Valley's Success Is So Hard to Replicate. *Scientific American*, *14*.

Jones, B. F. (2014a). The human capital stock: a generalized approach. *American Economic Review*, *104*(11), 3752–3777.

Jones, B. F. (2014b). *The knowledge trap: human capital and development reconsidered.* (Northwestern University Working Paper)

Juhász, R., Lane, N. J., & Rodrik, D. (2023). *The new economics of industrial policy* (Working Paper No. 31538). Cambridge, MA, USA: National Bureau of Economic Research.

Juhász, R., & Steinwender, C. (2024). Industrial policy and the great divergence. *Annual Review of Economics*.

Kaldor, N. (1967). *Strategic factors in economic development*. Ithaca: New York State School of Industrial and Labor Relations, Cornell University.

Krugman, P. (2009). The increasing returns revolution in trade and geography. *American Economic Review*, *99*(3), 561–571.

Kuznets, S. (1966). *Modern economic growth: Rate, structure, and spread* (Vol. 2).

Lerner, J. (2009). *Boulevard of broken dreams: why public efforts to boost entrepreneurship and venture capital have failed–and what to do about it*. Princeton University Press.

Levin, R. C., Klevorick, A. K., Nelson, R. R., Winter, S. G., Gilbert, R., & Griliches, Z. (1987). Appropriating the returns from industrial research and development. *Brookings papers on economic activity*, *1987*(3), 783–831.

Lewis, A. (1955). The theory of economic growth. *Milton Park: Routledge*.

Li, Y., & Neffke, F. (2023, March). *Evaluating the principle of relatedness: Estimation, drivers and implications for policy* (CID Research Fellows and Graduate Student Working Paper Series No. 146). Cambridge, MA: Center for International Development at Harvard University.

Lucas, R. E. (1993). Making a miracle. *Econometrica*, 251–272.

Lucas, R. E. (2004). *The industrial revolution: Past and future* (Vol. 18) (No. 1). Minneapolis: Federal Reserve Bank of Minneapolis.

Marshall, A. (1920). Industrial organization, continued. the concentration of specialized industries in particular localities. In *Principles of economics* (pp. 222–231). Springer.

Maskell, P., & Malmberg, A. (1999). The competitiveness of firms and regions: 'ubiquitification'and the importance of localized learning. *European urban and regional studies*, *6*(1), 9–25.

Mazzucato, M. (2015). *The entrepreneurial state: debunking public vs. private sector myths* (Revised edition. ed.). New York, NY: PublicAffairs.

Mega, E. R. (2017). Plans for a research powerhouse in the Andes begin to unravel. *Science*.

Mezzanotti, F., & Simcoe, T. (2023). *Innovation and appropriability: Revisiting the role of intellectual property* (Working Paper No. 31428). Cambridge, MA, USA: National Bureau of Economic Research.

Miguelez, E., Raffo, J., Chacua, C., Coda-Zabetta, M., Yin, D., Lissoni, F., & Tarasconi, G. (2019). Tied in: The global network of local innovation. *WIPO Economic Research Working Paper*, *58*.

Morrison, A., & Boschma, R. (2019). The spatial evolution of the italian motorcycle industry (1893–1993): Klepper's heritage theory revisited. *Industrial and Corporate Change*, *28*(3), 613– 634.

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1989). Industrialization and the big push. *Journal of Political Economy*, *97*(5), 1003-1026.

Murphy, R. (1999). Return migrant entrepreneurs and economic diversification in two counties in south Jiangxi, China. *Journal of International Development: The Journal of the Development Studies Association*, *11*(4), 661–672.

Naughton, B., & Segal, A. (2003). China in search of a workable model: Technology development in the new millennium. In W. W. Keller & R. J. Samuels (Eds.), *Crisis and innovation in asian technology* (p. 160–186). Cambridge University Press. doi: 10.1017/CBO9780511610059.007

Nedelkoska, L., Assumpcao, A., Grisanti, A., Hartog, M., Hinz, J. J., Lu, J., Hausmann, R. (2021, May). *The role of the diaspora in the internationalization of the colombian economy* (CID Faculty Working Paper No. 397). Cambridge, MA: Center for International Development at Harvard University.

Neffke, F. (2017). Coworker complementarity. *CID Research Fellow and Graduate Student Working Paper Series*.

Neffke, F., Hartog, M., Boschma, R., & Henning, M. (2018). Agents of structural change: The role of firms and entrepreneurs in regional diversification. *Economic Geography*, *94*(1), 23–48.

Neffke, F., & Henning, M. (2013). Skill relatedness and firm diversification. *Strategic Management Journal*, *34*(3), 297–316.

Pamuk, S. (1981). Political economy of industrialization in Turkey. *Merip Reports*(93), 26–32.

Pandey, A., Aggarwal, A., Devane, R., & Kuznetsov, Y. (2006). The indian diaspora: A unique case? *Diaspora networks and the international migration of skills*, 71–97.

Patel, D., Sandefur, J., & Subramanian, A. (2021). The new era of unconditional convergence. *Journal of Development Economics*, *152*, 102687.

Pineli, A., & Narula, R. (2023, June). Industrial policy matters: the co-evolution of economic structure, trade, and fdi in brazil and mexico, 2000–2015. *Journal of Industrial and Business Economics*, *50*(2), 399–444. Retrieved from https://doi.org/10.1007/s40812-023-00262-4 doi: 10.1007/s40812-023-00262-4

Priem, J., Piwowar, H., & Orr, R. (2022). *Openalex: A fully-open index of scholarly works, authors, venues, institutions, and concepts.*

Pritchett, L. (1997). Divergence, big time. *Journal of Economic Perspectives*, *11*(3), 3–17.

Rodrik, D. (2013). Unconditional convergence in manufacturing. *The Quarterly Journal of Economics*, *128*(1), 165–204.

Rodrik, D. (2022). An industrial policy for good jobs. *Hamilton Project, Brookings Institution*.

Rodrik, D. (2023, July 7). Focus on productivity, not technology. *Project Syndicate*.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102.

Rosenstein-Rodan, P. N. (1943). Problems of Industrialization of Eastern and South-Eastern Europe. *The Economic Journal*, *53*(210/211), 202-211.

Roser, M. (2014). Human development index (hdi). *Our World in Data*. (https://ourworldindata.org/human-development-index)

Rostow, W. W. (1960). *The process of economic growth* (2d ed.). Oxford, England: Clarendon Press.

Saxenian, A. (2006). *The new argonauts: Regional advantage in a global economy*. Harvard University Press.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. Harper and Brothers.

Scott, A., & Storper, M. (2003). Regions, globalization, development. *Regional studies*, *37*(6-7), 579–593.

Shapiro, C. (2000). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. *Innovation policy and the economy*, *1*, 119–150.

Shih, W. C. (2023). The new era of industrial policy is here. *Harvard Business Review*, *87*(9/10).

Smart, A., & Hsu, J.-Y. (2004). The Chinese diaspora, foreign investment and economic development in China. *The Review of International Affairs*, *3*(4), 544–566.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(1), 65–94.

The World Bank. (2023). *World Development Indicators.* (data retrieved from http://https:// databank.worldbank.org/reports.aspx?source=world-development-indicators)

UN Development Programme. (2023). *Human Development Report.* (data retrieved from https://hdr.undp.org/)

Weitzman, M. L. (1998). Recombinant growth. *The Quarterly Journal of Economics*, *113*(2), 331–360.

Williamson, J. (1990). What Washington Means by Policy Reform. In J. Williamson (Ed.), *Latin American adjustment: How much has happened?* (pp. 7–20). Institute for International Economics Washington, DC.

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