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Policies for Industrial Development, International Collaboration and Technological Sovereignty: Implications for Emerging Economies

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Introduction and Motivation

This short position paper introduces the concept of ***technological sovereignty in development*** as a guiding notion for future-oriented industrial development policy (Lee et al. 2023), derived from the current leading economy discourse on technological sovereignty. That concept suggests that the ambition of all countries should be to develop and retain a combination of own strengths and broad-based international collaboration. It posits that to improve the well-being of their constituency and to develop their industries' capacities to meet global standards, governments need to reinforce domestic capacities and at the same time benefit from external sourcing (Edler et al. 2020). In doing so, this paper underlines that the adequate balance between both efforts will depend on the ambition pursued. While, in a world of increasing geopolitical uncertainty (Acharya 2017; Brewster 2018; Hearson et al. 2018; Khandelwal 2020; Krapohl et al. 2021) and an increasing importance of power-play (Stiglitz et al. 2024), national security concerns may at times justify addressing issues exclusively on home soil, economic concerns will in the vast majority of cases continue to justify international outreach and global collaboration. This holds true with a view to cost considerations and even more so with a view to the sourcing of existing solutions and knowledge. As long as one-sided dependencies can be avoided (Edler et al. 2020) and countries do not come to unduly rely on the stability of single political relations, it thus endorses rather than question the established paradigm that economic development requires cooperation rather than autarky. Against this background, technological and economic sovereignty are defined as the ability of a country to develop and retain an independent agency in order to determine its own pathway to develop free of external constraint - without necessarily possessing all capacities itself (Edler et al. 2023; March et al. 2023). In more concrete terms, to develop a capacity of supporting its firms in assuming favourable positions within international value chains - through both domestic capacity building and the conscious management of international relations in science, technology and trade (Gereffi et al. 2013; Henderson et al. 2002; Kano et al. 2020; Yeung 2021). In that sense, discourses at the European level also speak of strategic autonomy, instead of technological sovereignty.

Developing countries are facing a similar challenge starting off from a quite different, initially not sovereign, position (Cimoli et al. 2008; Lee et al. 1988; Lee et al. 2021b; Rodrick 2007). Through domestic investments in education and the upgrading of the country's productive assets they are starting to build own capacities. They will, however, for a long time, remain more dependent on external investment and knowledge than established technology nations (Lee et al. 1988; Lee et al. 2021b), to the extent that external factors may prompt domestic institutional shifts (Hamilton-Hart et al. 2021). They are prone to suffer more directly in case of potential disruptions and have to be even more conscious to avoid vulnerabilities resulting from one-sided dependencies that expose them to concentrated risks related to the disruption of single international relations. At the same time, increasingly tense political relations between their potential development partners make it more difficult for them to embed their industrial development[1] effort and related policies in a broad, diverse and sufficiently redundant set of international collaboration opportunities. More often than was, the choice of one partnership may now either rule out that of another one directly (Capri 2020), or, even if it is temporarily permitted, risk the partial disintegration of a

[1] Here and subsequently, 'industry' will be used in the inclusive sense of the English term that includes all services directly pertinent to material products without which they could not become solutions. Also, it has the ambition to refer to the broader array of supporting services, such as logistics and maintenance, without which industrial activities could not take place. In line with common practice, it therefore continues to use the term 'industrial policy' for a broad array of efforts and measures that extend across all sectors of the economy. In doing so, it fully acknowledges that - even in pure assembly contexts - value creation comprises much more than the material production of artefacts.

country's web of development partnerships in case open conflicts force it to take sides (Stiglitz et al. 2024).

While this contribution will not assess whether taking sides or not is the better hedging strategy, it starts from the observation that an increasing number of developing nations has once more been moved into a position that cannot be considered politically neutral vis-a-vis either of the world's leading nations. Against this background, it will explore the best possible options for an industrial policy that safeguards nations' sovereignty over their development process in light of a now more restricted choice of possible partners.

1 Innovation Driven Development

Fundamentals - A brief review of the literature

All economic development and lasting favourable positioning in international value chains (Coe et al. 2008) rests on a country's capacity to accumulate sufficient human capital and knowledge domestically to eventually move into a position to innovate and realise technological progress independently (Grossman et al. 1991; Kim 1997; Kim et al. 2000; Lall 1992; Liu et al. 2017). Establishing such a capacity is a gradual process that rests on different preconditions and opens up specific, new avenues for further development at different stages (Lee et al. 1988; Lee et al. 2021b). The essence of our contemporary understanding of economic development thus is that it is a dynamic, stepwise and cumulative process and that industrial policy requires constant adjustment. In the course of a country's development (Eum et al. 2022; Wade 1990), it has to be gradually extended to further domains (Lin et al. 2009; Radosevic et al. 2018) and eventually enable countries to embark on sovereign paths of developing own distinctive economic strengths (Lee et al. 2023; Lin 2012; Liu et al. 2017). Hence, there can be no simple one-dimensional answer to the historic fundamental dispute whether developing nations will profit from the engagement with leading economies (Grossman et al. 1991; Hirschman 1968; Krueger 1997; Krugman 1994; Ohlin 1933; Prebisch 1959, 1962) or whether the potential dangers of that may on occasion prevail.

What has unanimously been established, however, is that, regardless of outward orientation, development can only ensue if there is a constant effort directed towards own capacity building in the field of education, industrial capabilities and, eventually, also the domestic transfer of knowledge and technologies between science organisations and industries (Bell et al. 1993; Lee et al. 1988; Lee et al. 2021b; Lee et al. 2023). Without such efforts, the countries will remain in a passive position in global value chains and subject to external decision making and power networks (Coe et al. 2015; Dicken 2007). At the same time, both economic theory and historical experience caution that while such capacity building will need the domestic mobilisation of means, the success of all industrial development policy will at the same time depend on its capacity to enable an external influx of leading-edge knowledge and the collaboration with, at least initially, technologically more competent partners (Amin 2002; Gereffi 2019; Grossman et al. 1991; Lee et al. 2023; Narula et al. 2010). Learning is a cumulative and, more importantly, an emergent process. Genuine progress can hence only be achieved in collaboration with the experienced, in a process of strategic coupling - i.e. the conscious and strategic engagement in certain types of partnerships accompanied by the readiness to decline others (Yeung 2016).

Over the past decades, therefore, development economics has clearly established that successful industrial development policies with the ambition to help nations transcend the middle income trap (Eichengreen et al. 2013; Gill et al. 2007; Lee et al. 2021a) can only be realised through different types of collaboration with foreign partners which develop gradually over time (Lee et al. 1988; Lee et al. 2021b; Lee et al. 2023). In light of the proven, and consequential, failure of many import substitution policies, most emerging economies have come to rely on export-based development, with substantial success and far into the development process.

In their process of gradual capacity building, all developing countries pass through three main stages that need to be accompanied by industrial development policy (Lee et al. 2023): fundamental capacity building in education and industrial production, industrial upgrading through imitation and learning and, finally, developing independent innovative capacities and catch up with the technological frontier (Eum et al. 2022; Lee et al. 1988; Lee et al. 2001; Lee et al. 2021b).

During the early stages of development, developing countries have next to no domestic technological capacity to the extent that domestic firms and research organisations display very limited absorptive capacity (Cohen et al. 1990) for external knowledge (Bell et al. 1993; Cimoli et al. 2008; Kim 1999; Lee et al. 1988; Lee et al. 2021b). Most of the public sector's tax income is generated by both foreign and domestic companies' production activities that leverage cost advantages (Lall 2000). On its own, this cost-based model of revenue generation does not offer lasting prospects for further development. While a country may have production capacity in "technology sectors", these may be rather unrelated to genuine technological capabilities in the field (Eum et al. 2022). Hence, it will remain difficult to motivate either multinationals or domestic assembly plants to engage more actively with their local environment - given the limited educational attainment of the local population and the limited absorptive and hence collaboration capacity of most local firms. Apart from supporting domestic firms in leveraging cost advantages, the best available "international option" for governments is to attract foreign companies with sufficient own capacities to operate independently and to re-invest the resulting tax income to improve domestic education and training systems (Cimoli et al. 2008; Wade 1990). At this stage, the capacity gap between external investors and local knowledge agents remains too large to provide local governments with any relevant leverage to anchor multinationals' commitment in anything else than cost advantage and make it more permanent. In nations where cost-based production depends primarily on foreign investors, a strong dependence on external technological capacities (Lee et al. 2023) and exposure to foreign corporate decisions results in a situation of structural dependency which may have a political element as well. In any case, countries are at this stage of their development very dependent on an unhindered outflow of goods that allows their exports to reach foreign markets as well as - in case of assembly production - the inflow of intermediate products.

Subsequently, the country enters the most critical stage in the development process in which international collaboration is leveraged for learning to gain an improved positioning and some level of agency in global value chains (Lee et al. 1988; Lee et al. 2021b; Liu et al. 2017; Vivarelli 2016; Wade 1990). Also to avoid the so-called "middle income trap" which could result from a country failure to transcend a follower status in technological terms (Gill et al. 2007; Lee et al. 2019, 2021a). Over time, sufficient investments in the educational attainment of the working population, on-the-job training in firms and the basic upgrading of production facilities have put domestic firms and technology organisations in a much more favourable position to obtain knowledge from local foreign investors or even the world market directly - through imports, imitation or re-engineering (Bell et al. 1993; Kim 1997; Lee et al. 2021b). On the one hand, this results naturally from a much increased mastery of standard production and development processes which allows a more qualified workforce to digest external knowledge inputs and to render them fruitful for their own, specific application contexts (Kim 1997, 1999; Liu et al. 2017). First attempts at domestic modular or architectural innovation are typically made at this stage, i.e. at innovations that rearrange existing technological components to serve markets better (Kroll et al. 2021), while information asymmetries and lack of capacity keep entrepreneurs from putting forward something fundamentally new (Hausmann et al. 2003; Hausmann et al. 2007). On the other hand, knowledge absorption from global investors can be notably facilitated by industrial policy support for local human capital circulation between foreign investors and domestic firms as well as exploratory re-engineering to access state of the art knowledge in spite of intellectual property protection by market leaders (Lee et al. 2023; Liu et al. 2017). Accordingly, domestic actors start to unfold conscious and targeted foreign interactions in the innovation domain, while at the same time they continue to depend on them (Eum et al. 2022). While they do not yet bring in their own knowledge, they have developed a much clearer understanding of what skills are required domestically, and scout for them in different ways. The channels through which knowledge is obtained are at this stage diverse. If there are foreign invested firms, most international flows of knowledge may still occur within those, technologies are acquired in

the process of production (Eum et al. 2022; Kano et al. 2020; Yeung 2021) in a process of strategic coupling (Yeung 2016). Yet, some representatives of companies and technology organisations will begin to actively engage with international expert communities. At this stage, international sourcing equates international sourcing of state of the art knowledge without which no further technological progress can be made. Should this not happen, the country may swiftly fall back to stage one.

At the same time, domestic technology transfer is often not yet in the focus of industrial policy attention because domestic technology organisations are still lagging behind the global state of knowledge. They are unable to make suitable offers to either advanced foreign investors or advanced domestic firms, both of which may be technologically ahead of them (Kroll et al. 2010).

Finally, the country has succeeded in bringing its industrial capacities up to standard and improved not only its basic education and training but also its higher education system (Kroll et al. 2010, 2013). Domestic firms may not have fully developed their products' standard to that provided by foreign investors or offered through local sales offices, but the gap has become narrower. Accordingly, foreign investors have to begin to invest into research and development locally to remain up to date with the specific market's requirements, lest they begin to lose out against domestic firms. In the industrial domain, the exchange of knowledge has thus become bi-directional with local firms starting to gain leverage as they possess knowledge that most foreign investors do not. In parallel, domestic technology organisations have improved their capacities to a standard that they can participate in scientific exchanges at the global level (Kroll et al. 2010). While they may not yet be among the key contributors, they are able to source relevant knowledge globally and transfer it to relevant domestic partners back in their home country. They also develop own, distinctive areas of specific capacity (Lee et al. 2001; Lin et al. 2009; Lin 2012) - directionality has shifted with the production process which is now informed by the scientific domain of technological development (Eum et al. 2022). At this stage, industrial policy becomes innovation policy and scientific collaboration, one of the key channels of international knowledge transfer (Kroll et al. 2022c; Lee et al. 2023; Wang et al. 2021). In fact, it may replace some of the initially more important channels. The more developed the local industrial context, the more cautious international investors will become with a view to disclosing knowledge without specific motivations, even to local employees whom they may swiftly lose again to an increasingly dynamic local job market. At the same time, local firms will have lobbied their own government to establish a more reliable domestic intellectual property system to protect their own achievements - which, in turn, also limits their ability to conduct overt reengineering with impunity (Kim et al. 2012; Kroll 2011, 2016). At this stage, international relations have become collaborative in many ways (Kroll et al. 2022c; Wang et al. 2021). In industrial terms, the country has become a respected partner and in the scientific domain is developing into a new contributor to be increasingly reckoned with (Frietsch et al. 2019; Kroll et al. 2022a; Kroll et al. 2022c). To a larger extent than before, the country will at this stage be able to compensate failures of international collaborations and in some domains even be able to sustain its position or even advance without external input, albeit much more slowly. Nonetheless, it will never be able to fully catch up with established leading nations in scientific or technological terms, lest constant, close exchanges with actors based in those can be maintained.

Types of international collaboration and their role for development

In line with the above said, international cooperation plays a central role at different stages of the development process (Lee et al. 1988). Without international collaboration, no country can build the capacities needed to advance technologically and, in consequence, economically beyond a middle income status (Binz et al. 2017; Coe et al. 2008; Coe et al. 2015; Gereffi 2019; Lee et al. 1988). As has been demonstrated, different objects, channels and mediators of exchange are important in different ways (Gereffi et al. 2021). At diverse stages of the development process, a lack of access

to them could result in bottlenecks that prevent further advances in development and a repositioning in the value chain (Coe et al. 2019; Gereffi 2019; Giuliani et al. 2005).

Informed and guided by the notion of ***technological sovereignty for development*** it is the task of industrial development policy to prevent those and advance international exchanges actively, in line with the current stage of development (Figure 1, Figure 2).

Firstly, international collaboration is a ***source of income and capital*** (Coe et al. 2015; Eum et al. 2022; Kim et al. 2000; Lall 2000; Wade 1990) which industrial policy should help mobilise for development at the initial stages. Without these initial means, no development efforts can succeed. As such, this income does not have to derive from technological activities. Some countries have for example actively leveraged income gained from natural resources for that purpose. However, it has at times proven a suitable first step into later upgrading if the initial cost based activities were at least in a sector that is amenable to later upgrading. For example, microelectronics assembly has in some cases provided a basis for local engineers to gradually acquaint themselves with the products and solutions with which they later engaged more deeply. Over time, this contribution of foreign direct investment wanes, as activity in domestic firms picks up and the local government is able to generate tax income from other sources. The main mediators of this first type of relations are foreign firms.

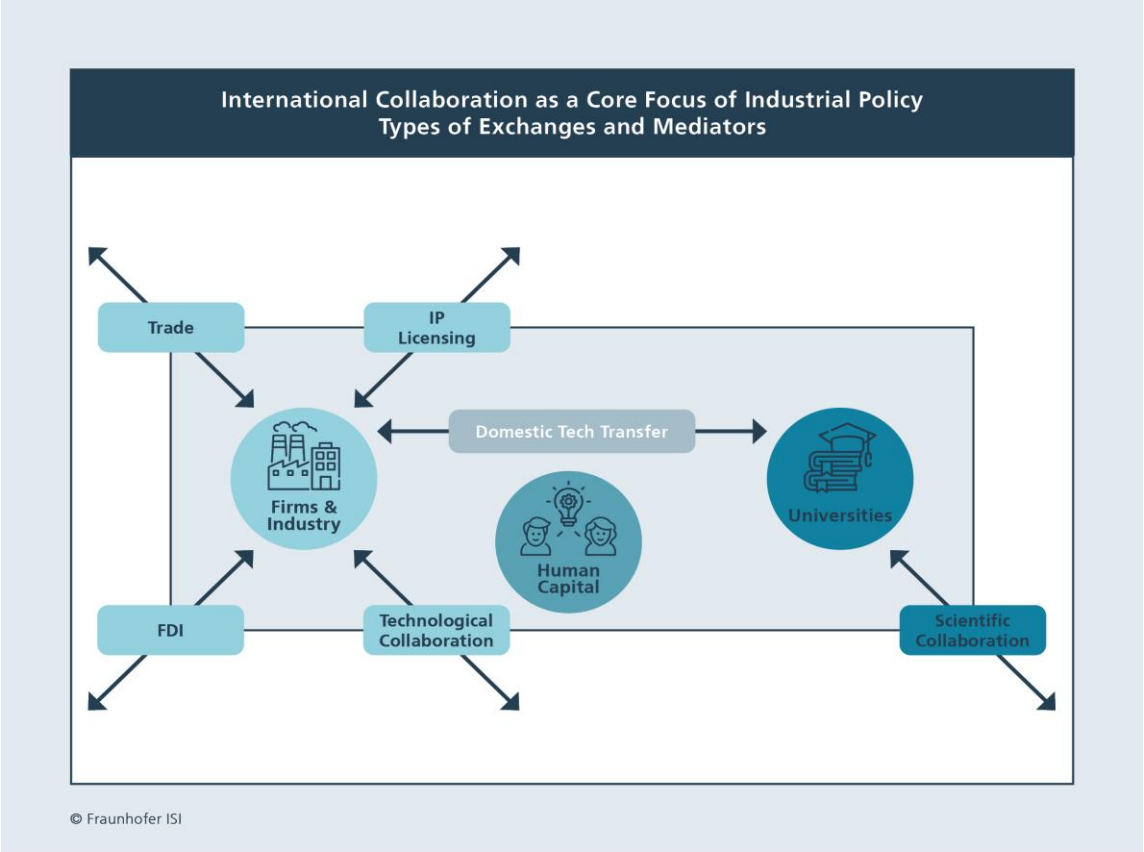
Second, international collaboration guarantees ***access to complete technology goods*** (Bell et al. 1993; Coe et al. 2015; Edler et al. 2020; Kim 1997, 1999; Kroll et al. 2022c; Lee et al. 2021b) at the early stages before a country's firms can produce or even actively engage with them. Without stable access to technological goods and services, countries will have difficulty to build the infrastructure required to attract foreign direct investment as well as to upgrade domestic firms' and technology organisations' production capacity to a level that guarantees a sufficient level of absorptive capacity (Cohen et al. 1990). At this stage, whilst the country it is not yet able to produce competitive technology goods, industrial policy needs to support access to those investment goods relevant for the modernisation of the domestic manufacturing facilities. Subsequently, it will remain important for re-engineering and the integration of existing and domestically tailored solutions in architectural innovation. At this point it is oftentimes strongly accompanied by the licensing of foreign intellectual property rights. In fact, even very developed economies continue to obtain a large share of their investment goods from foreign sources, so while access to foreign goods may become less essential during later stages of catch-up it will continue to play an important role (Amin 2002; Binz et al. 2017; Boschma 2022). The main mediators of this second type of relations are domestic firms and technology organisations acquiring equipment.

Third, countries depend on ***collaborations in the technological domain*** (Kim 1999; Kroll et al. 2012; Kroll et al. 2022b; Kroll et al. 2022c) which allow knowledge and experiences to be transferred into the country, be they primarily within a corporate context or inter-organisational (Boschma 2024; Dannenberg et al. 2018). These become relevant at a later stage when foreign companies have transferred first development capacities into the respective developing economy context and selected domestic companies have reached a level of technological expertise that allows them to collaborate with foreign firms (Kroll et al. 2013). At this point in time, co-patenting becomes a relevant issue although it typically still reflects a situation in which a foreign headquarter or home country development department interacts with a local branch or partner for market adaptation. These types of collaboration, which industrial policy can foster, guarantee knowledge flows at a stage when the country is moving beyond improving its absorptive capacities to building own capacities of creative knowledge generation and collaboration. While particularly crucial at the stage when a country is developing first endogenous innovation capacities, this type of collaboration remains central among the technologically most developed economies. Even when the domestic

science-industry nexus is substantially improved, much knowledge will still enter the country directly within the industrial sector. During the early stages of development, the primary mediators of this third type of relations are foreign firms and their local subsidiaries, later joined by domestic firms as a local partner and, yet later, by those starting off collaborations with own foreign subsidiaries.

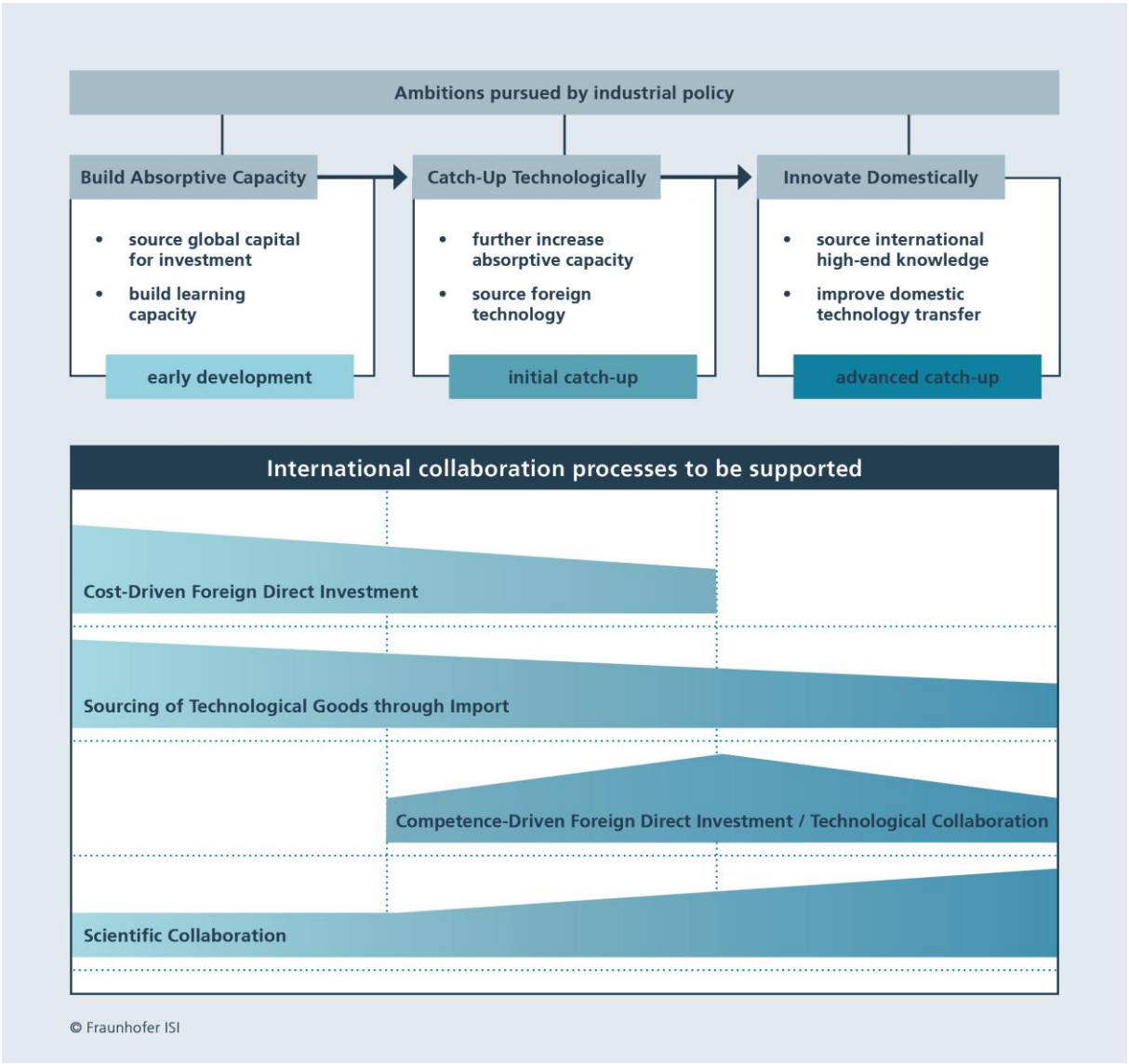
Finally, ***collaborations in the scientific and high-end technology domain*** (Eum et al. 2022; Kroll et al. 2022b; Kroll et al. 2022c) become more relevant at the very end of the catch-up process, when the country is approaching the technological frontier. Certainly, some fundaments of scientific relations need to be created early so that they can be readily built upon later when the time comes. Also, they play some specific roles from the very beginning, e.g. in exposing domestic professors and teachers to the state-of-the-art in technological development. However, they can only unfold their full potential once an improved domestic technology transfer system has been put in place. At the early stages, when this is not yet the case, international knowledge sourced by academics too often remains within the domestic academic sphere and thus unproductive in terms of economic development (Kroll et al. 2010). Once science and industry interact more smoothly, knowledge obtained within the international academic community will be swiftly translated and relayed to relevant domestic industries and/or empower local technologists to develop home-grown solutions based on the international state-of-the-art (Kroll et al. 2010). Moreover, it is particularly relevant in situations where - for one reason or another - the country's international integration through foreign-direct investments is less pronounced. The main mediators of this fourth type of relations are domestic universities and technology organisations.

Figure 1: International Collaboration as a Core Focus of Industrial Policy Types of Exchanges and Mediators



Source: own summary, in reference to Lee et al. (1988); Lee et al. (2021b)

Figure 2: Timeline of Key Tasks of Industrial Development Policy



Source: own summary, in reference to Lee et al. (1988); Lee et al. (2021b)

2 Technological Sovereignty for Development

A new concept - Summing up known insights concisely

The concept of ***technological sovereignty*** has evolved in the context of a developed economy, where scientific and technological leaders are struggling with a situation in which an increasingly unstable geopolitical environment is forcing them to reconsider their established dense international network of scientific and technological relations (Bauer et al. 2020; Crespi et al. 2021; Edler et al. 2020; Edler et al. 2023; March et al. 2023). While the underlying idea is old (Grant 1983), recent geopolitical shifts (Khandelwal 2020; Krapohl et al. 2021; Stiglitz 2017) have infused the topic with renewed relevance and have made it one on the fundamental economic debates of the day. No less than the question whether proven models of upgrading industrial capacity in emerging nations can be upheld under inclement geopolitical conditions is at stake and, if so, in what way.

According to Edler et al. (2020), technological sovereignty is given when a nation has sufficient own technological capacity and can rely on external technological resources free of one-sided dependency. It is absent when there are either insufficient own capacities or the complementary sourcing of knowledge that is also needed has become too concentrated on single partners. The underlying assumption is that there can be no sovereignty without own capacity and that, at the same time, the level of complexity of current technologies and value chains nearly rules out that any one country will be able to muster sufficient own capacities to address complex challenges in autarky.

While the recent increase in geopolitical tensions (Khandelwal 2020; Krapohl et al. 2021; Luo et al. 2023; Stiglitz 2017) was the primary and in itself novel trigger of this discussion, three underlying structural vulnerabilities that aggravated its techno-economic implications had developed over time. First, the cost-based offshoring of production capacities (Cassia 2010; Dicken et al. 2001; Fröbel et al. 1978; Grunwald et al. 1985) has reached an extent which has in some cases prompted a substantive loss of process and in the meantime also product innovation capabilities among former technological leaders. Second, increasing technological complexity has created a situation in which it has become next to impossible to effectively re-shore complete innovation chains including all required auxiliary inputs and competences in all but the biggest countries (Boschma 2024; Coe et al. 2019; Gereffi et al. 2013). Third, a number of formerly emerging economies, most prominently China, have not only reached the technological level of established leaders, but in part have surpassed it (Kroll et al. 2022a; Kroll et al. 2022b). All this has made established technology nations' position in global value chains more fragile and increased the potential impact of them being cut off from central inputs or collaboration partners for political reasons.

Previously, these countries' position was stabilised and increasing gaps in competence covered through robust networks of cooperative relations (Dicken 2007; Gereffi et al. 2005; Gereffi et al. 2013; Yeung et al. 2015). At that time, it was enough to excel in certain areas and to rely on external competence in most others. With the recent proliferation of political tensions and tangible adversarial actions, however, it is often no longer possible to choose freely among feasible partners at least not without incurring substantive risks (Kroll 2024). As a result re-fragmentation - or at least re-balancing - of established, politically agnostic networks of economic integrations appears to be underway which restrains the availability of options to compensate own shortcomings through partnerships (Lund et al. 2020; Yeung et al. 2023; Yeung 2023). Whether a world thus newly fragmented into spheres of interest and delineated domains of integration will still provide a sufficient diversity of options for the choice of those partnerships that guarantee sovereignty, does no longer appear certain leading firms and nations to consider new strategies (Gao et al. 2023). In that light, even formerly fixed views regarding the relative cost of re-shoring or friend-shoring (re-location to

other partners) are being re-visited (Elia et al. 2021; Pla-Barber et al. 2021; Sekliuckiene et al. 2023; Yeung et al. 2023).

Developing economies are facing that very same situation from quite a different perspective (Lee et al., 2023; Rodrik/Stiglitz, 2024). As their own capacities are absent (Lee et al. 1988) they can by definition not be sovereign at the beginning of their development process, regardless of how international relations are structured (Dicken 2007; Gereffi 2019). In a very literal sense, they are thus aiming to move from a situation of technology-economic dependency into one of greater sovereignty (Yeung 2016). To achieve this, they will have to invest into the development of own capacity and at the same time govern their international relations strategically. Until the very final stages of catch-up, they remain in a positon in which any concentrated dependency on external knowledge inflows could be very easily exploited should any of the key partners so choose out of political considerations. At the same time, they become exposed to singular, concentrated risks more easily once they choose to engage with one specific international development partner one whom they subsequently begin to depend.

Other than in leading economies, their industrial policy cannot yet be directed at defending an established status, but focuses on developing agencies and to gradually gain sovereignty over their development process. As has been outlined above, diverse factors are needed to make this happen, some of them financial but most of them, sooner or later, knowledge related. Without an independent capacity to innovate and by itself contribute to the shaping of world markets, no country can depart from structural dependence and/or improve its position in global value chains (Gereffi 2019; Lee et al. 2023). This, too, has been substantially complicated by the re-emerging fragmentation of the global system (Gao et al. 2023). As mentioned above, the competences that a developing country would want to source are often distributed across a number of leading economies, not all of which belong to the same political camp. While the most obvious current fault line exists between the US and China further may emerge between Europe and China, the US and the EU or elsewhere in the coming years. In earlier, political more agnostic years, developing economies' industrial policy could seek purpose-bound partnerships according to primarily commercial or otherwise pragmatic considerations (Coe et al. 2015; Dicken et al. 2001; Gereffi et al. 2013). Today, the situation is no longer that simple (Gao et al. 2023). While situations in which mutual embargoes formally bar those collaborating with one partner from collaboration with another remain comparatively rare, more indirect challenges have been abound in recent years. First, the current level of geopolitical tensions makes it more difficult than in the past for any developing country to remain completely neutral, resulting in a lack of partners from the other block to even offer collaboration in the first place. Second, even countries that still succeed in establishing partnerships with development partners from different sides must be aware that this approach would collapse should open conflict ever break out.

What this entails is that the common, post-colonial principle of most developing nations to not ground their development strategy in one primary partnership alone has become more difficult to realise. If, in a newly fragmenting world, even leading nations must avoid one-sided dependencies, this is even more important for developing nations. For them, the exposure to the risk of primary partnerships failing has potentially far more dire consequences than it has for developed countries that can fall back on a more developed basis of own capacities should the need arise. Per se less autonomous developing nations, in contrast, may be left without any access at all to relevant resources.

At the same time the new situation also offers opportunities for industrial policy. As the world economic system is at risk of disintegrating into separate economic blocks which are each under-critical in size, leading economies are reaching out to additional partners. They may now be willing to accept further emerging economies as partners in new roles and at a level for which they previously

maintained a fixed set of selected relations. While geopolitical tensions have now rendered some of these established partnerships less reliable, their own means to domestically re-shore against marker forces is limited as is the number of qualified, trusted partners that could on their own substitute for large, established partners. In that situation, a new openness towards diverse development partnerships that may help attenuate this problem might well emerge.

3 Emerging Nations' Exposure to Partnership Risks in Collaboration

Challenges and opportunities in a newly fragmenting world

In light of the above said, the following challenges and opportunities for developing countries' industrial policy can thus be identified:

First, the geopolitically driven re-organisation of global value chains may cut off some developing countries from their current sources of cost-oriented investment. At the same time it may open up opportunities to profit from re-shoring and diversification by major investors. On the one hand, countries can no longer pool investment from all advanced nations easily. This is an issue in particular for those nations that had begun to profit from Chinese or Indian FDI alongside that from established Western nations. On the other, they may benefit from the fact that, for the first time for years, several leading nations have developed a substantial interest to divest from established production bases and build up alternative production sites. To some degree, selected countries had been able to profit from such divestment before. They did however offer notable cost advantages that were able to compensate for their more weakly developed logistics and availability of local component suppliers. With the risk component now much more prominent in commercial considerations, such weaknesses now even could motivate foreign investors to upgrade the local infrastructure rather than to abstain from engaging with the respective country altogether. Also, the diminished need for ruinous cost-side competition and 'welcome packages' for firms could increase local governments' potential gains in terms of tax incomes.

Second, the availability of technology goods through imports has become an issue in particular for those countries which take a political position less aligned with those nations who provide the most affordable investment goods needed for technological upgrading. While, at this level, genuine sanctions remain rare, developing nations will have to choose between paying more to ascertain safe delivery or accept the risk of paying less. At times, needed political alliances will now have to be weighed against unhampered access to the most affordable goods needed for industrial development. More generally, redundancies will have to be built in terms of the supply of relevant investment goods which will in some cases increase the monetary price for development. Likewise, the increasing efforts of some leading nations to become self-sufficient again, not only technologically but also to a degree, in terms of domestic production. They may redirect some flows of goods to their domestic markets, reducing the availability of relevant goods on the world market, or at least making their prices less favourable. As an ultimate consequence of this tendency of leading nations to become more inward-looking, developing countries may eventually also have to consider the development of domestic offerings earlier than in the past. While most of the lessons of import substitution still apply today, it will be more often required to weigh up the increased cost now associated with global sourcing. This must be done against the problematic, but known, cost associated with domestic production at rather early stages.

Third, it is against this background absolutely essential to maintain, safeguard and diversify reliable and effective technological collaborations with other nations that ensure the inflow of knowledge. For that knowledge to develop an impact on the business sector swiftly, relevant collaborations will have to be anchored in the industrial domain. Precisely because of this foreseeable, immediate impact, it is this area that has become jeopardised most. More so than for pure cost-based investment which is, by itself, less relevant for development, leading nations have begun to choose their partnerships in this area more strategically - and more oriented towards political and economic safety. Reasons for this are dual use as well as commercial risk considerations. In this area, it will

therefore become most difficult to uphold a politically fully agnostic approach to international engagement. In any case, developing nations need to be aware and prepare for situations in which they have to take clear sides in the light of open conflict and - as a consequence - would lose part of their existing technology oriented FDI or at least see their inflow diminished. At the same time, much of leading nations' qualified FDI inflow had in the past years become concentrated on a small number of best developed emerging markets. Even so, they were also home to the best first or second tier suppliers. From a purely commercial standpoint, there would have been very limited reason to change this set-up for years to come. With increasing uncertainty in these relations, however, many corporate actors are now actively beginning to search for potential alternative locations. And in this search, they may at times even be willing to invest into a broader upgrading of human capital and production facilities and encourage re-location of suppliers - with potentially very beneficial effects.

Fourth, the domain of science remains comparatively least affected. Other than high-quality foreign direct investment it does directly entail commercial risks and it is also often less directly problematic from a dual use perspective. While science has become a politically contested field between leading nations also, the related preoccupation of losing the cutting-edge insights to potential adversaries appears far less critical in either side's scientific collaboration with developing nations (Hou et al. 2021; Kroll et al. 2022b). Hence, an openness to collaborate irrespective of political positions often remains - not least in light of the increasing urgency of fundamental, and shared, global challenges. Even when many other types of collaborations become fraught with risk and potentially unstable, this option for knowledge sourcing thus appears to remain most accessible. For developing countries this may imply that more effort will have to be dedicated to the upgrading of domestic structures for technology transfer. This is to put them in a position to reap the benefits of scientific collaboration earlier, at stages where one would in earlier years still have primarily relied on corporate FDI without any specific concern.

An overview of the current situation, specific bottlenecks and risk areas

In the following, we will analyse the de facto exposure of a number of relevant developing nations which are positioned in the middle stage of development. On each continent, the study focuses on five nations which have on the one hand moved beyond the very early stages of the development process and developed a certain basis of techno-economic capacities on all continents. These countries are:

- America: Argentina, Brazil, Colombia, Mexico, Peru
- Europe: Bulgaria, Greece, Romania, Serbia, Turkey
- Africa: Egypt, Morocco, Nigeria, Tunisia, South Africa
- Middle East/Central Asia: Azerbaijan, Iran, Jordan, Kazakhstan, Saudi Arabia
- South and East Asia: Indonesia, India, Malaysia, Thailand, Viet Nam

As Figures Annex 1 - 4 illustrate, their science and technological capacities remain one to two orders of magnitude below those of mid-size leading economies like Germany, Japan and Korea. But they are present and have sufficient scope to support an analysis. On the other hand, countries that have next to successfully completed the process of catch-up like China, Singapore or Korea are not included as this would require a more historical perspective than the available data could enable.

In line with what our model of development phases suggests, Figure 3 illustrates that the relation of foreign direct investment to gross domestic product has decreased in most of the analysed countries. Some of the most developed ones among them have turned to become foreign direct investors themselves most recently. This suggests that, economically, they have been able to markedly decrease their dependency on multinationals' investment as a basis for development. A greater share of productive assets is now under national management than was, and an overt dependency

in this area at least less of a worry. The only countries where such a trend is not visible, or less so, are Vietnam, Indonesia and India which have profited from a relocation of investments from China.

Likewise, we find that most of the countries here considered remain externally dependent with a view to high-tech trade relations (Figure 4). In the domain of high-tech goods, next to all of them display negative trade balances which have in most cases also not significantly improved in the past decade. In Malaysia, Thailand and Vietnam, as well as arguably Bulgaria, Greece, Turkey and Tunisia, improvements in trade balances may indeed reflect technological upgrading or at least an improved capacity to domestically generate and retain value added in high-tech industries. In Malaysia, Romania and Thailand, overall trade balances have even turned neutral or slightly positive.

On a positive note, we also find that the diversity of export partners that these emerging nations are catering for has increased rather than decreased over the past decade. With a few exceptions, the share that the Top-3 export partners hold in overall exports has decreased, rather than increased (Figure 5). Very likely, exceptions in Egypt, Kazakhstan, Peru and Mexico may reflect geopolitical particularities rather than consequences of a growing or changing techno-economic potential for exports. Once they have reached the stage of development in which they become providers - or at least producers - of high-tech goods, emerging countries do not seem to overly depend on specific markets.

On the other hand, import dependence on the Top-3 import partners (Figure 6) has grown substantially over the past decade, reaching more than 60% in most cases. More specifically, the share of the most important import partners, in all but one case China, has increased to nearly 50% in most cases (Figure 7). This is a substantial change from the situation a decade ago when China did not yet unilaterally assume this role and the share of the Top-1 import partners amounted - on most occasions - to 20-30% rather than to nearly 50%. Thus, there is clear evidence of the hypotheses put forward in the conceptual section that emerging countries have become more dependent on single providers of resources, parts and intermediate goods, most prominently China. The reason for this can in some, mostly Asian, cases be interpreted as an integration into new, emerging value chains, now governed by Chinese corporations, that start using emerging countries as a production basis with a more favourable cost environment - as production in China itself has become more expensive. At the same time, countries in all parts of the world have come to rely ever more extensively on affordable and increasingly advance Chinese input, as an effect independent of geographies.

In line with these remaining dependencies in the domain of trade, Figure 8 demonstrates that most of the countries here considered now display higher, rather than lower relative rates of technological collaboration and hence potential dependency than advanced nations. Apparently, their embeddedness in international corporate structures, as measured in co-patents, is on average two to three times higher than that of a developed economy like Germany. And, with the exception of Peru, it has not decreased much anywhere outside the Middle East during the past decade. With a few exceptions and some structural differences the same holds true for the share of domestic inventions that are subsequently owned by foreign organisations, as documented in Figure 9. In some cases, continued limitations to technological autonomy are even clearer from this perspective than with a mere view to co-patents (cf. Argentina and Saudi Arabia). Only in the rather specific case of Iran, as well as in Jordan and Tunisia has this relation fundamentally changed. From a different angle, this impression of persistent dependencies is corroborated with a view to trends in the balance of payment for intellectual property which are increasing in all countries for which information is available, even when normalised by gross domestic product (cf. Figure 10). The sole exception is once more Tunisia (data for Iran and Jordan are not available).

In technological terms, concentrated and thus potentially risky dependencies exist by and large vis-a-vis the United States, although it would amount to hyperbole to call them unilateral anywhere

outside Saudi Arabia. However, while the role of the US as key partner amounts to about 20% in a developed, broadly integrated nation like Germany and even in Japan only to about 30%, it can be up to 45% in India and about 50% in Mexico. In South-Eastern Europe, Africa, and, from a different angle, East Asia, technological dependencies are less pronounced as these have other relevant partners as well, not least among the leading European economies. Here, dependencies on one lead partner hardly exceed 20-30% at par with those in developed economies. Also, the situation does not aggravate anywhere outside Saudi Arabia. While some relative intensification of external control can be observed in Brazil, Mexico and Tunisia none of this reflects fundamental, structural changes. In the same vein, the limited decreases in Thailand and Vietnam should not be over-interpreted as sea changes. While international technological integration and dependency does not fade, despite building US-Chinese tensions, it does not substantially intensify either.

With a view to scientific collaborations, to the contrary, next to all countries analysed by this study have increased the share of international collaborations among their scientific publications during the past decade. Only Vietnam, Indonesia and Peru display a contrary trend. In some countries, a substantive national surge of - part limited quality - publications has not been fully matched by international collaborations. In relative terms, increases in collaboration are highest in Eastern Europe and Africa (cf. Figure 11). In East Asia, absolute growth is at least equally high, but often matched by a parallel build-up of national capacity so that relative shares do not change, or less so.

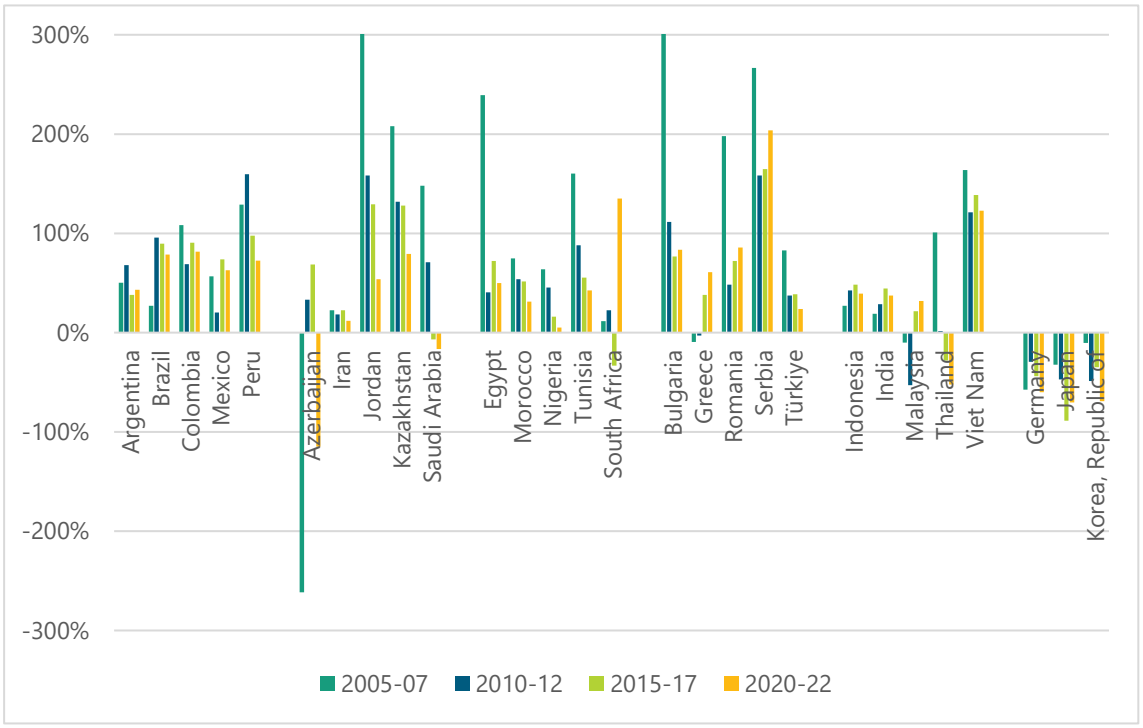
As Figure 12 further underlines, the concentration of collaborations in the academic field is typically notably lower than in the technological or investment domain. Also, they are on average lower than in established scientific nations which focus on each other's activities to a larger degree. Even in Latin America, the focus on the US hardly exceeds 30-35%. The only exception from this general rule are former Soviet Republics where the scientific orientation towards Russia is still very pronounced. While China has gained in relevance as a partner in part now comparable to that of the US, is in general terms not overly dominant either. In Europe and Africa, European lead nations (often former colonial powers) continue to play an important role.

A slightly different perspective emerges with a view to the knowledge resources that developing and emerging economies tap into through academic citations (Figure 13). Typically, more than 50% of all academic citations in emerging nations refer back to publications from three leading academic powers, the US, the UK and, increasingly, China (in some cases, still other European nations or India). From a perspective oriented more towards future potential, the above declaration of academic collaboration as unproblematic with a view to concentration thus needs to be put into perspective. While current patterns of collaboration may be more dispersed and less fraught with economic control mechanisms than in the technological domain, there is still a very limited number of primary sources of academic knowledge. Furthermore, two of the three most important sources have substantive political disagreements. While the nature of publication ascertains that access to knowledge can be guaranteed without personal interactions, any genuine further development of knowledge, or even participation in its benefits, would require joint learning. Should a country be limited to sourcing either side's insights through documented, codified knowledge only, this would be a clear limitation to the development process. So as much as current collaboration appears unproblematic, the underlying structure of citations reveals that challenges may still lie ahead.

Finally, Figure 14 provides insights into the focus countries' build-up of scientific capacity - as reflected in the degree by which they can rely on own, prior work in developing new academic knowledge. In most of the countries here considered this share ranges between 2.5% and 5%, much lower than the 15% common in many established scientific nations. Contrary to the developments in the domain of scientific collaboration, this last stage of capacity building does not seem to have begun in many countries in the past decade - with the notable exception of Brazil and India.

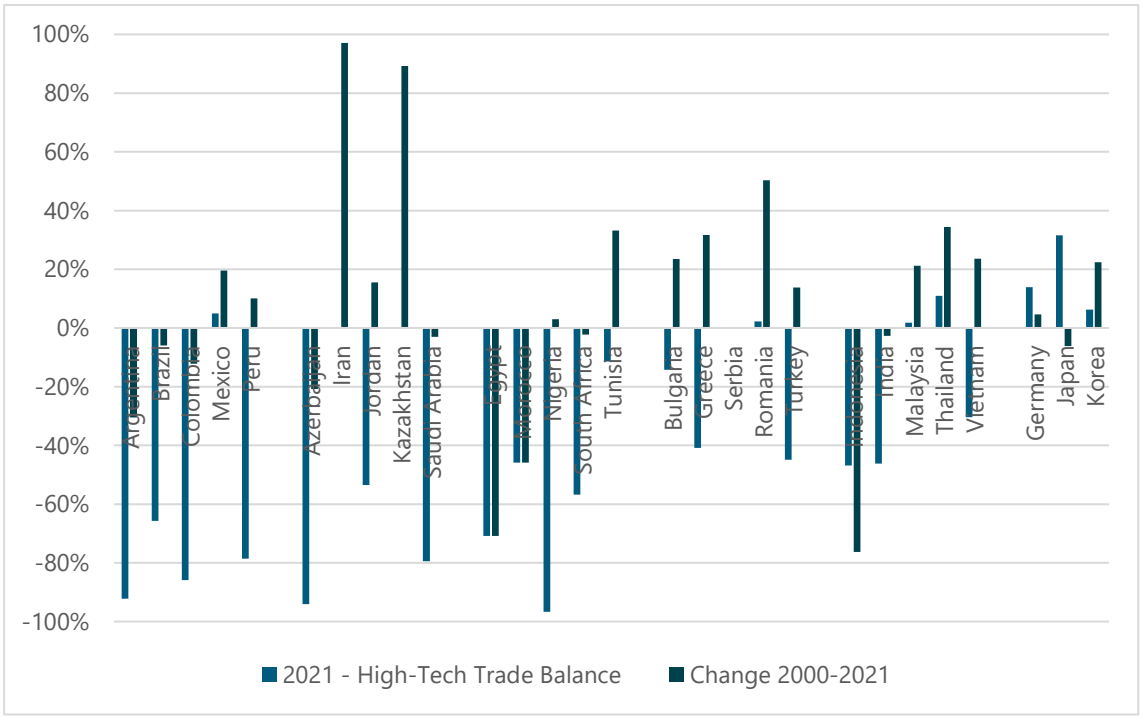
While there are a great number of particularities pertaining to specific countries and their political and economic circumstances, our analysis thus clearly confirms our conceptual suggestions. In the countries considered here, the past decade has seen a decrease in the importance of foreign direct investment, relative stability in the domain of technological engagement and an increase in scientific collaboration. In the domain of trade, few countries have managed to substantially attenuate their dependency on high-tech imports. While they serve multiple markets, their reliance on China as a key source of supplies and final products has substantially increased. Directly, this holds for the Asian and Eastern European nations here considered. If specificities in Iran, Kazakhstan, Mexico and South Africa are disregarded, the observation also holds for the remaining three groups of African, Middle Eastern and South American nations here looked at.

Figure 3: Development of foreign direct investment (net inflows) over GDP



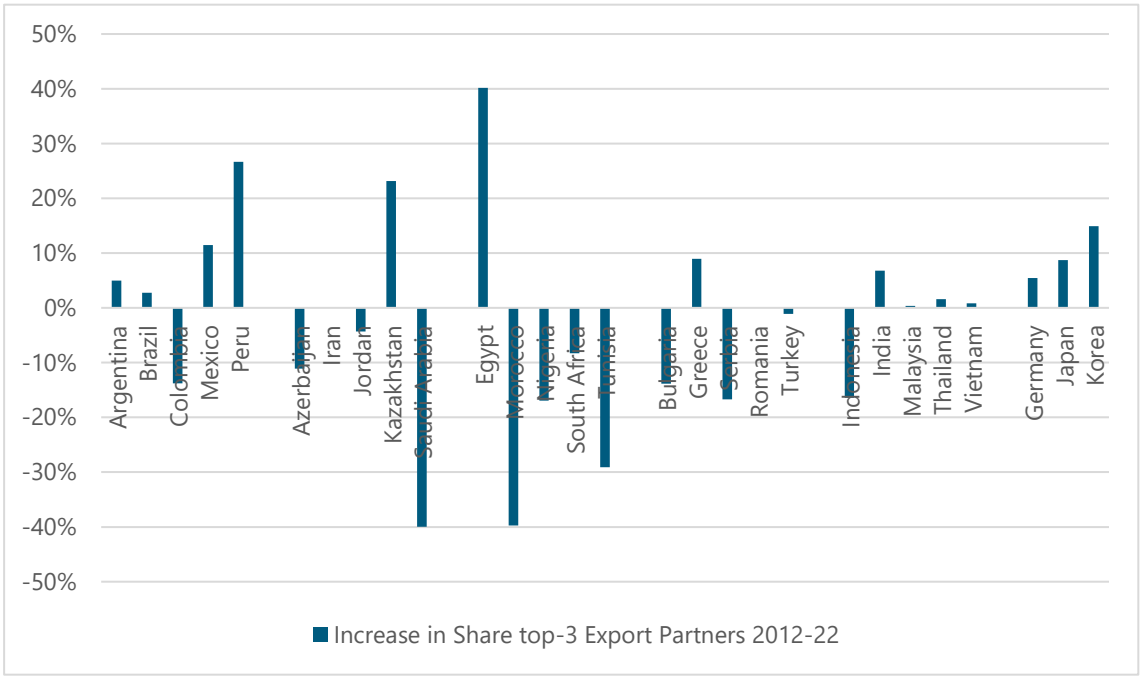
Source: Analysis by Fraunhofer ISI, based on World Investment Report

Figure 4: Development of High-Tech Goods Relative Trade Balance over Time



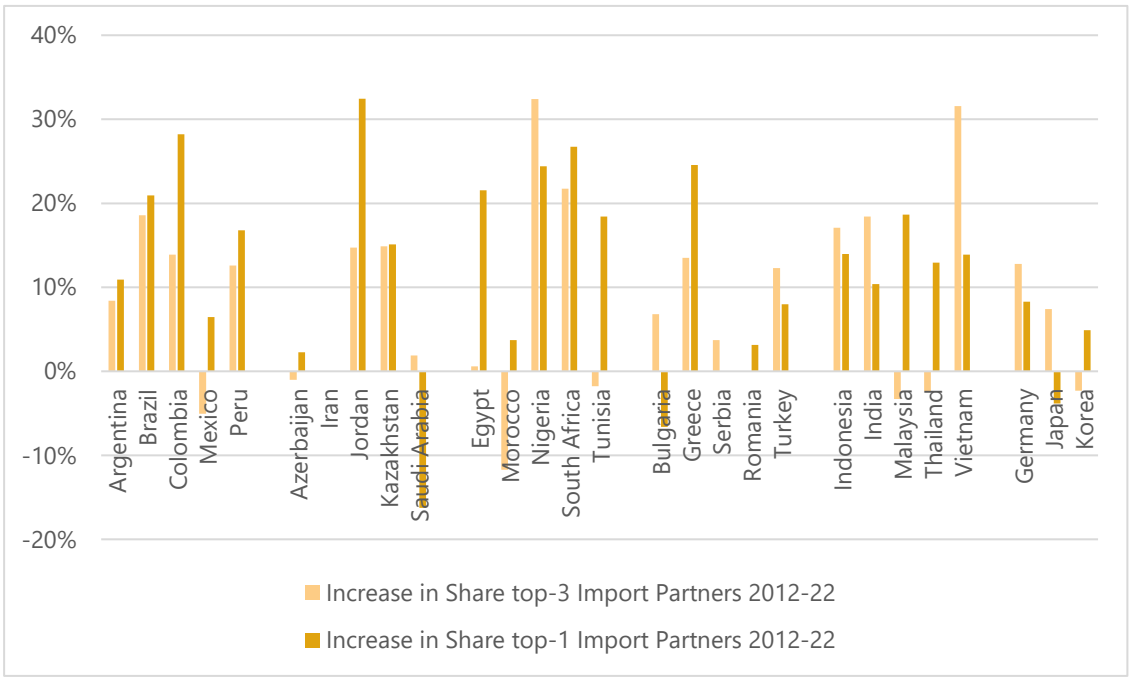
Note: The relative trade balance is defined as (export-imports)/export+imports);
High-tech goods refers to a group of goods defined in the European Commission's ATI project
Source: Analysis by Fraunhofer ISI, based on UN COMTRADE

Figure 5: Development of Shares of Top-3 Export Partners in all Exports, 2012-22 (Concentration of High-tech Exports)



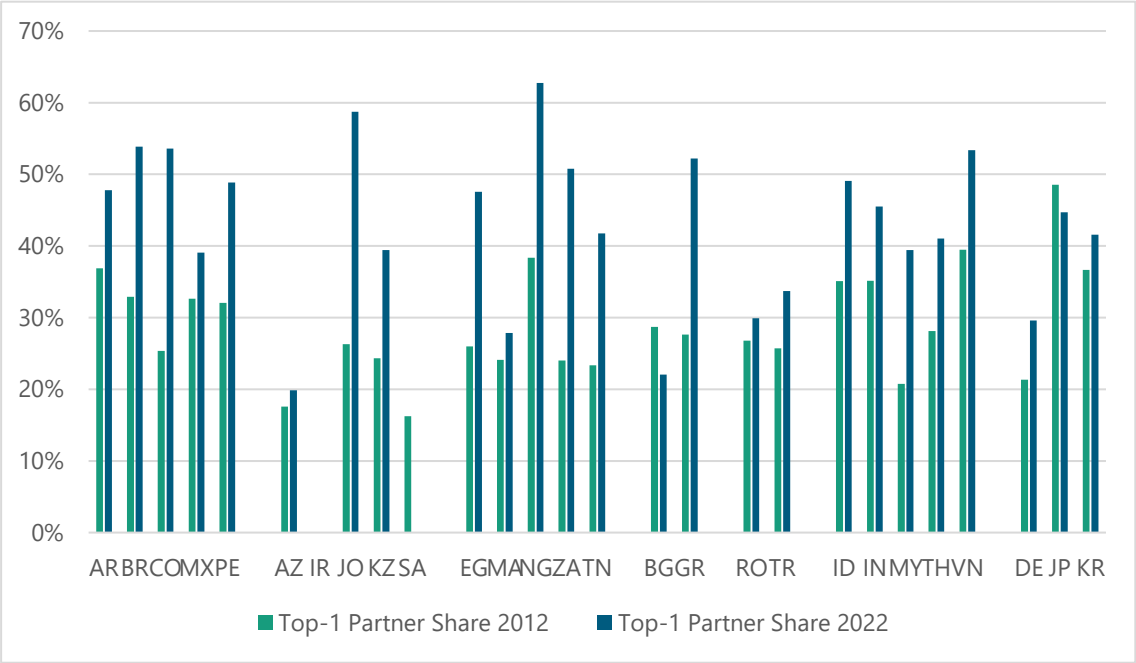
Note: High-tech goods refers to a group of goods defined in the European Commission's ATI project
Source: Analysis by Fraunhofer ISI, based on UN COMTRADE

Figure 6: Development of Shares of Main Import Partners in all Imports, 2012-22 (Concentration of High-tech Imports)



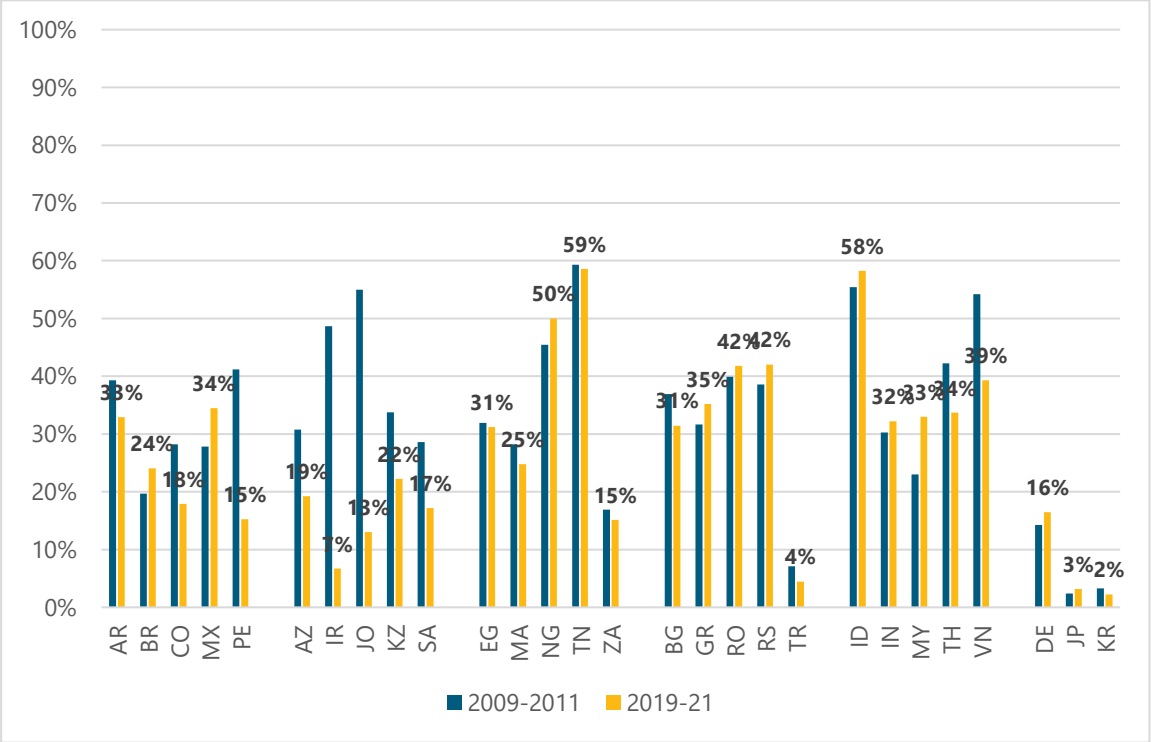
Note: High-tech goods refers to a group of goods defined in the European Commission's ATI project
Source: Analysis by Fraunhofer ISI, based on UN COMTRADE

Figure 7: Development of the Share of Top Import Partner in all Imports, 2012-22 (Concentration of High-tech Imports)



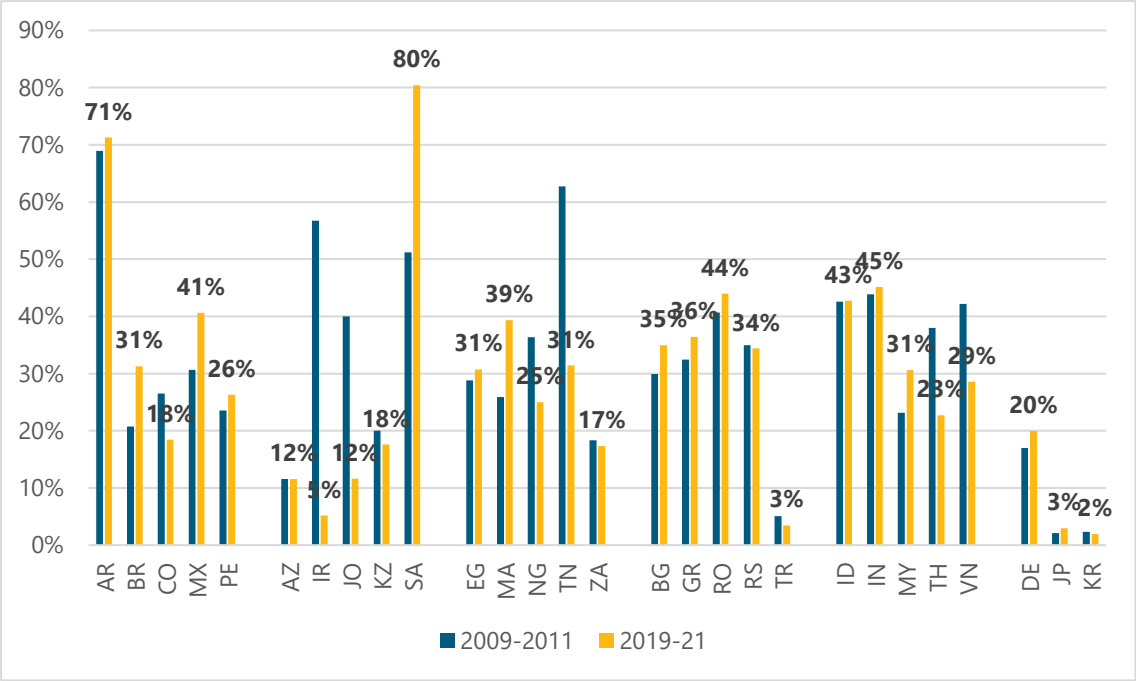
Note: High-tech goods refers to a group of goods defined in the European Commission's ATI project
Source: Analysis by Fraunhofer ISI, based on UN COMTRADE

Figure 8: Share of Co-Patents in all Patents



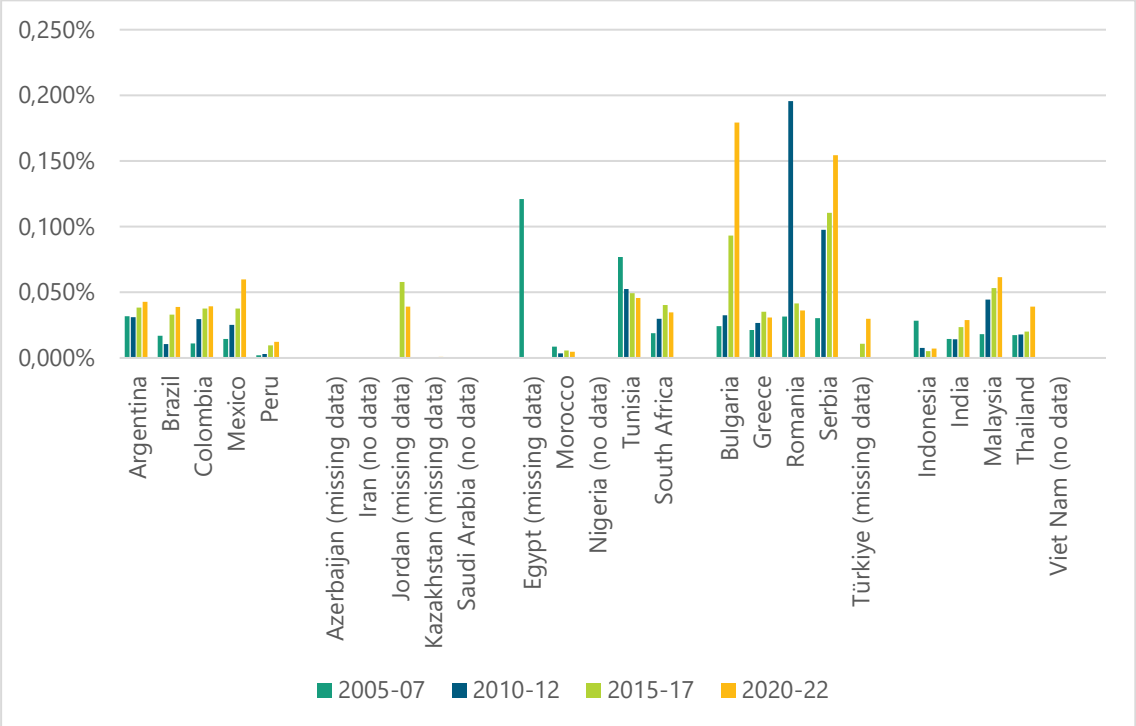
Source: Analysis by Fraunhofer ISI, based on EPO Worldwide Patent Statistical Database (PATSTAT)

Figure 9: Share of Externally Owned Domestic Inventions in all Patents



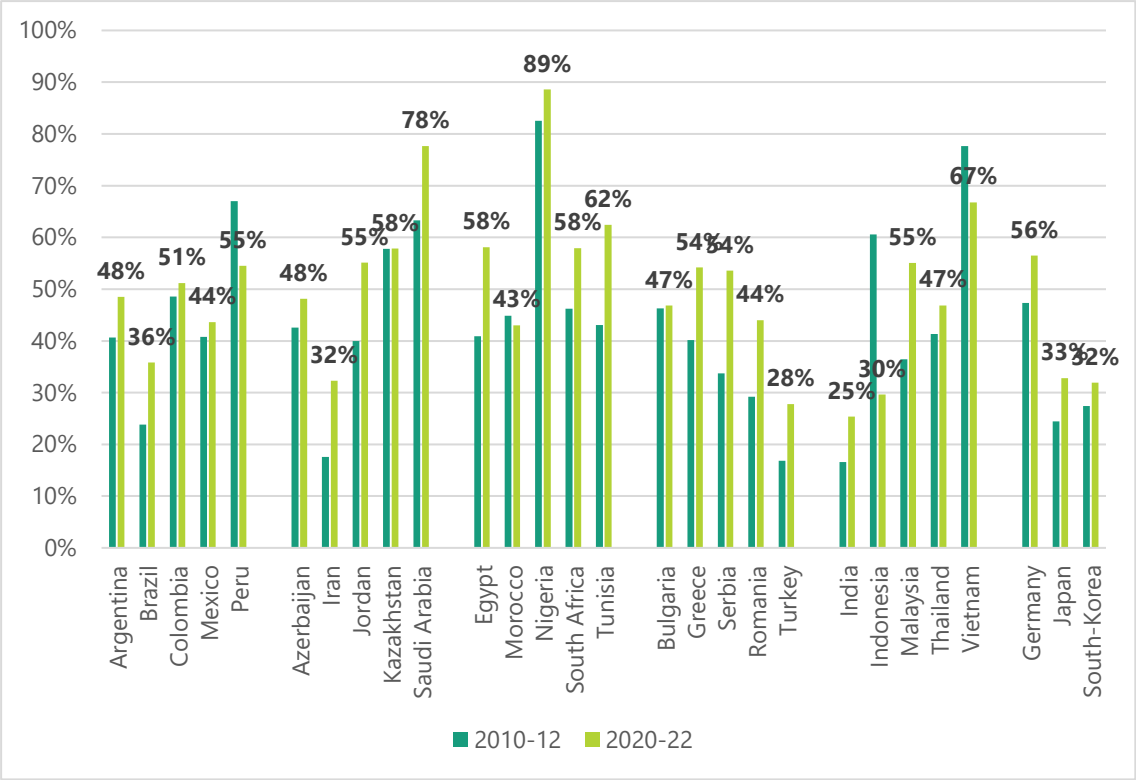
Source: Analysis by Fraunhofer ISI, based on EPO Worldwide Patent Statistical Database (PATSTAT)

Figure 10: Balance of Payments for Intellectual Property per GDP (%)



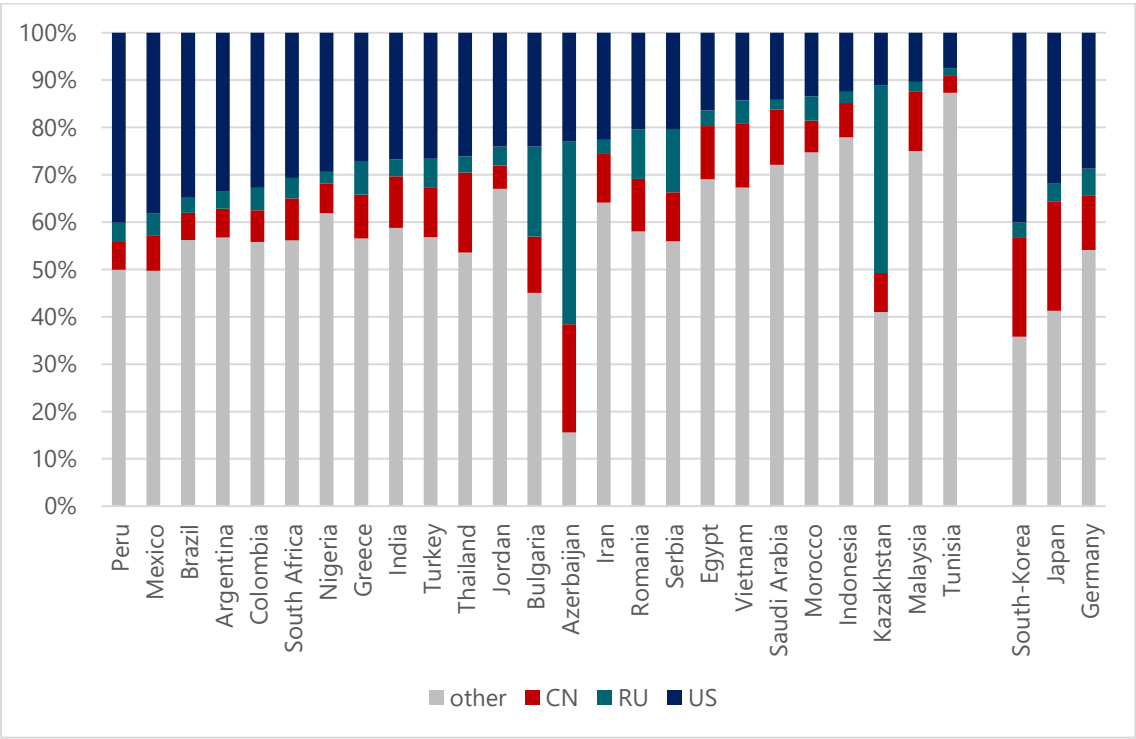
Source: Source: Analysis by Fraunhofer ISI, based on World Development Indicators

Figure 11: Share of Co-Publications in all Scientific Publications



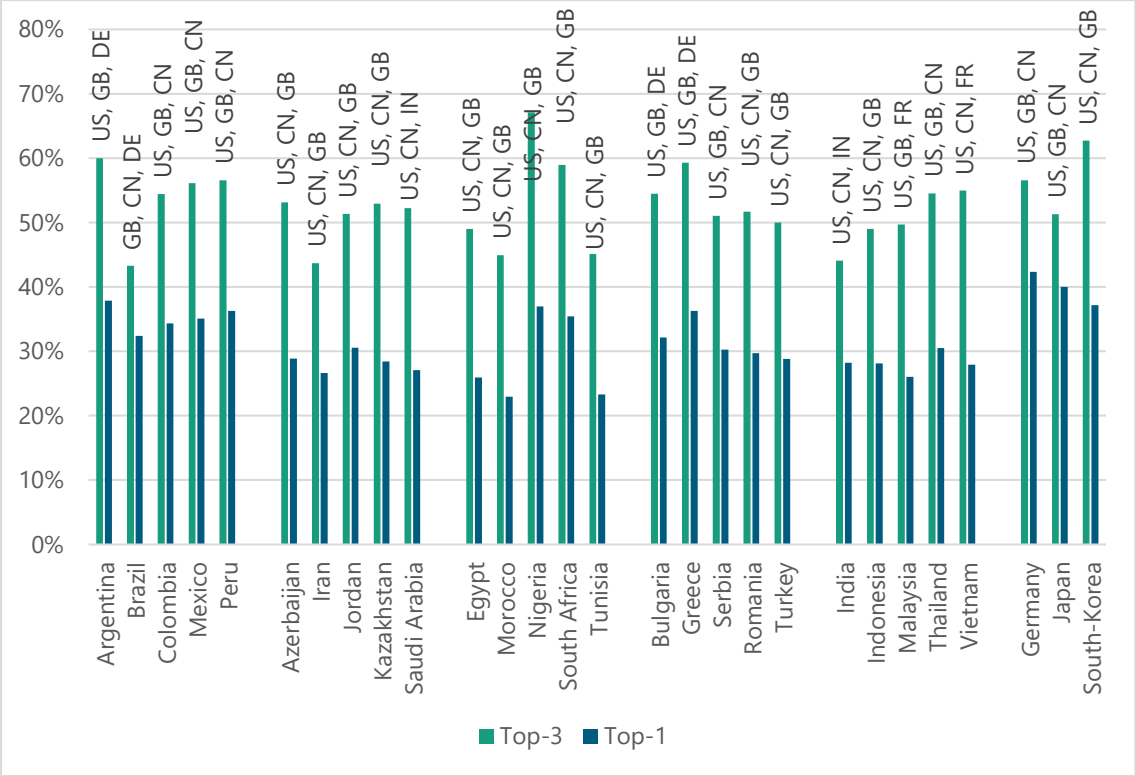
Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

Figure 12: Share of Scientific Co-Publications by main partners



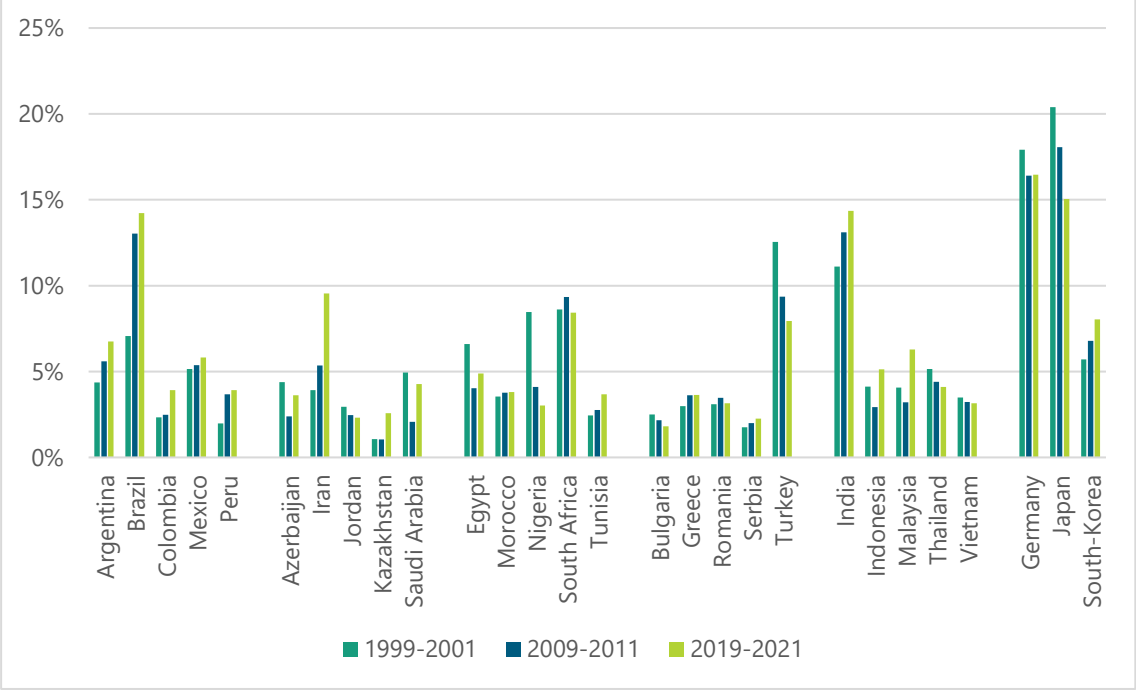
Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

Figure 13: Top-3 / Top-1 Countries' Share in Total Citations



Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

Figure 14: Development of the Share of Domestic Citations over Time



Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

4 Conclusions

In light of the above said, the recent and persistent increase in geopolitical tensions must be considered as detrimental as it limits opportunities for both export-based development in general, and international learning with the aim of technological upgrading more specifically. Overall, it will make it harder rather than easier for emerging countries to overcome the middle income trap through innovation driven development. Following the analysis above, we must conclude that the traditional path to economic sovereignty through strategic coupling have - to a degree - been put at jeopardy.

In the geopolitical context, with fewer reliable partners available, developing countries' economic policy makers will have to re-align their cost-benefit assessments with a view to building technological capacity. While realism in terms of identifying suitable leverage points for policy is still advisable, it will become more risky to either entirely rely on external partners or to develop own capacities 'in dependence' of others for too long. However, it may offer some opportunities for developing nations also.

In any case, however, they will have no choice but to consciously address the new realities lest they want to play a substantive price in terms of domestic social welfare.

While it has always been necessary to consciously reinvest gains from cost-based investment to build own capacity and human capital, starting to do so early has become more critical in the light also of the increasing cost of technology imports from second best partners.

While it has never been advisable to rely on knowledge input from one single source too readily, it has now become fundamentally problematic - in particular in those cases when a political alliance with that main provider could not be upheld in the case of conflict.

While it has always been desirable that scientific development as well as that of a functioning domestic technology transfer system was put on the agenda early, the much higher risk of blockage of other channels now makes such an investment even more indispensable.

In consequence, developing countries will have to pursue an economic policy that safeguards foreign direct investment to the degree possible, using measures of diversification and making the best possible use of the ongoing re-location efforts of major international corporations. At the same time, they need to rely less readily on the natural training effects and spill-overs that come with such foreign investments. In a world characterised by increasing uncertainty other channels, like the scientific one, have to be developed further and domestic capacities for processing knowledge will become more essential. If foreign direct investment is still relied on, it should be based on solid risk assessment and - in consequence - mostly originate from trusted partners who have a substantive own interest in developing their investment environment further.

To achieve technological sovereignty and overcome the middle income trap in the new situation emerging country policy makers will thus have

- to acknowledge that while economic development will not be possible without external input, this external input has become less reliable,
- to avoid situations of concentrated reliance on single partners by diversification, and, if inevitable, choose those with whom the country intends to be allied,
- to be even more conscious of the need to build own capacities for the production of investment goods. However, more importantly, the capacity to productively process different types of international knowledge domestically.

A prime example of this are the "China plus One" strategies pursued by many US-American and European firms, which, as a concept, date back to the 2010s (Economist 2010[2]), but have dynamically gained in importance since[3]. At the same time, Chinese companies are on their part seeking to diversify markets[4], accompanied by strategies to upgrade local capacities as well as capacities to improve domestic science industry collaboration. Nonetheless, the implementation of such policies remains by and large the domain of developed nations and, even there, remains far from consequential[5].

As this contribution has argued, emerging economies would be well advised - and well positioned - to follow more developed nations in these efforts. While the current positioning of Vietnam[6], India[7], Indonesia[8], Thailand[9] and others as 'plus one' countries for investment is one important element of adapting to the current geopolitical shift - it remains a by and large passive reaction. In addition to a mere investment perspective, emerging nations, not least those outside Asia, need to consciously de-risk their own networks of partnerships of technological collaboration and learn to ramp up investment in local capacities. Failing that, the current increase in geopolitical uncertainty will substantively limit their options of overcoming the middle income trap.

[2] www.economist.com/asia/2010/09/02/plus-one-country

[3] www.mckinsey.com/mgi/our-research/asia-on-the-cusp-of-a-new-era

[4] www.channelnewsasia.com/commentary/china-plus-1-one-southeast-asia-singapore-asean-tencent-alibaba-751806

[5] www.economist.com/graphic-detail/2023/11/14/dont-be-fooled-by-americas-new-supply-chains

[6] www.vietnam-briefing.com/news/china-plus-one-strategy-vietnam-latest-issue-vietnam-briefing-magazine.html/

[7] www.india-briefing.com/news/india-china-10664.html/

[8] https://thediplomat.com/2021/06/which-asian-nations-can-benefit-from-the-china-plus-one-strategy/

[9] www.spglobal.com/marketintelligence/en/mi/research-analysis/asean-china-plus-one-destination-current-situation-risk-outlook.html

From an economic policy perspective, this implies that, under the new geopolitical conditions, emerging countries at a more advanced stage of their development process need to address the triple challenge of

- promoting the build-up of autonomous capacity in domestic industries which can be sustained and improved with less foreign direct investment,
- consciously managing technological relations, avoiding one sided relations but foreseeing potential conflicts. There is benefit in direct, industrial collaborations, but a real challenge is posed by biased dependencies,
- building domestic transfer capacity to better profit from science collaborations as the currently most resilient and dynamic knowledge and learning network.

Following the line of argument presented in this paper, there are thus three main domains in which new approaches need to be considered and new proactive opportunities for emerging country policy makers may appear (Table X).

- First, in the established domain of policy support to foreign direct investment as a source of tax income to enable further development, including e.g. efforts to invest in education and infrastructure.

  These are the areas where we currently see most emerging activities (e.g. of the "plus one" type), yet - according to many - in part still without sufficient vigour and without leveraging their full potential.

- Second, in the area of targeted policy to support the import of critical technology goods, technological collaboration and the licensing of intellectual property to increase the absorptive capacity in industry, including parallel efforts to create domestic tech-transfer capacities.

  In this area more relevant for overcoming the middle income trap, even fewer activities can currently be detected. While the U.S., Europe and also China are have developed contingency plans for scenarios in which access to critical technology providers is lost, few such efforts are found in emerging nations.

- Third, industrial (and innovation) policy support of scientific collaborations which help to create the basis for domestic innovation capacities. They enable a genuine technological catch-up with established leaders.

  Some emerging economies indeed display activities to develop their international collaboration in science and technology and at the same time invest in domestic transfer capacities. However, the degree of resources committed to those and their strategic orientation leaves room for improvement in many cases.

Overall, developed and emerging nations are united in the challenge to manage an unfortunate and economically detrimental situation by re-balancing their collaboration based on a sober risk assessment, while avoiding to lose touch with earlier key partners entirely. After all, there is a strong remaining hope that, from a secular perspective, current geopolitical disagreements will - in their current form - pass.

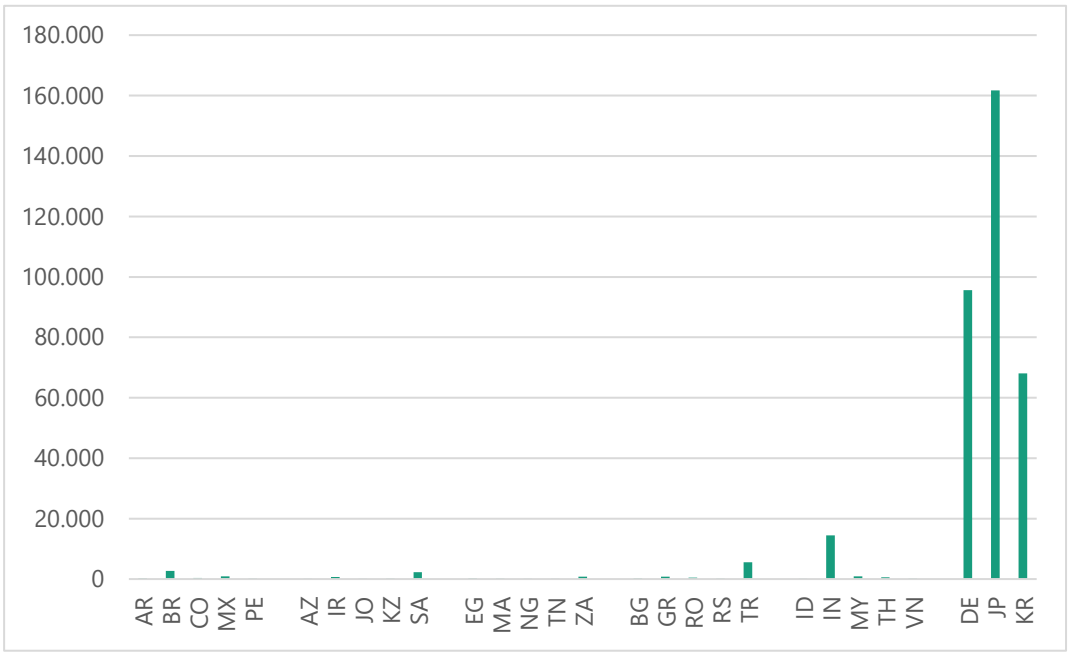
Table 1: International Collaboration in S&T at Different Stages of Development, Conclusions for Industrial Policy acknowledging Specific Aspects of Sovereignty

	cost-based FDI	trade, technological collaboration, IP licensing	collaboration in science & high-tech
primary relevance for	early stage; low income	mid-stage; low to middle income	late stage; middle to high income
required domestic capacity serving as basis	cost-advantage for production	capacity for learning and re-engineering	domestic tech-transfer capacity
benefit of relation	financial capacity to upgrade	absorptive capacity in industry	domestic innovation capacity
generic task of industrial policy	invest in education required for learning	accelerate industrial upgrading	support technological catch-up with leaders (innovation policy)
vulnerability	high, mostly footloose	mid-range, market based	low, competence based
degree of politicisation	low	high	medium
Number of potential partners	high	low	low

Source: own concept / illustration

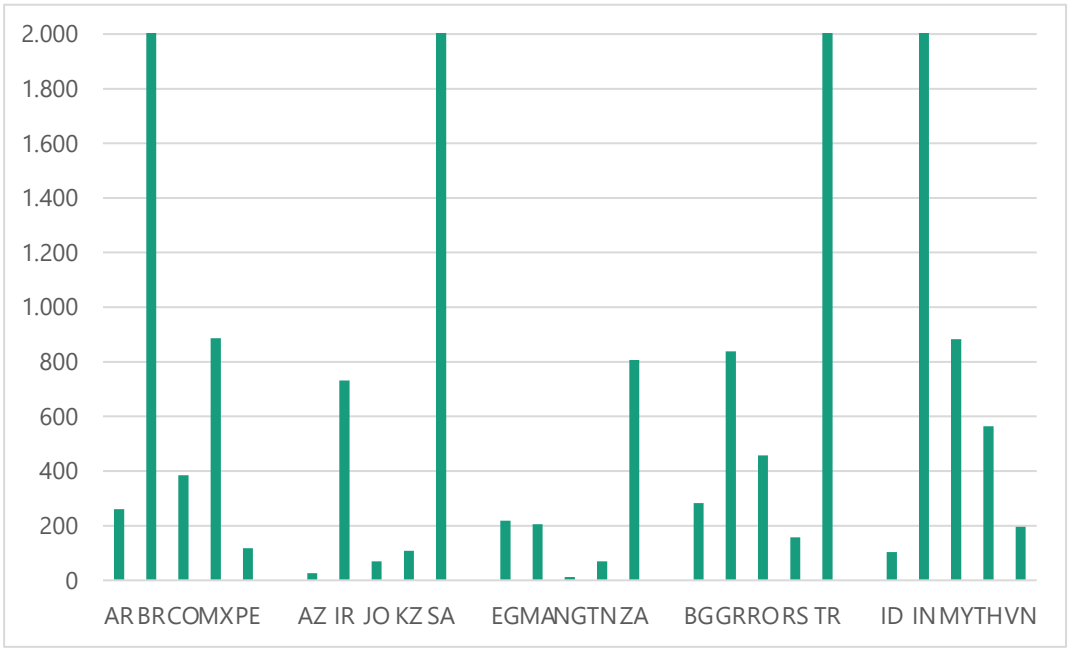
Annex

Figure A 1: Total Number of Patents, sum 2019-21



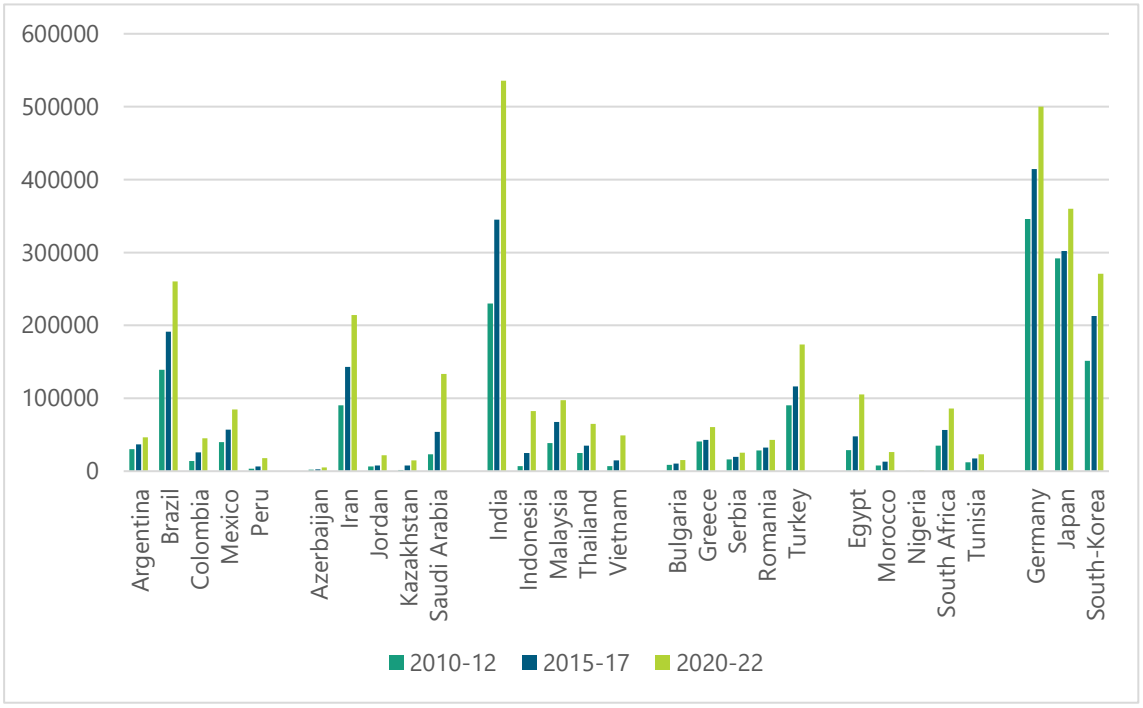
Source: Analysis by Fraunhofer ISI, based on EPO Worldwide Patent Statistical Database (PATSTAT)

Figure A 2: Total Number of Patents, sum 2019-21



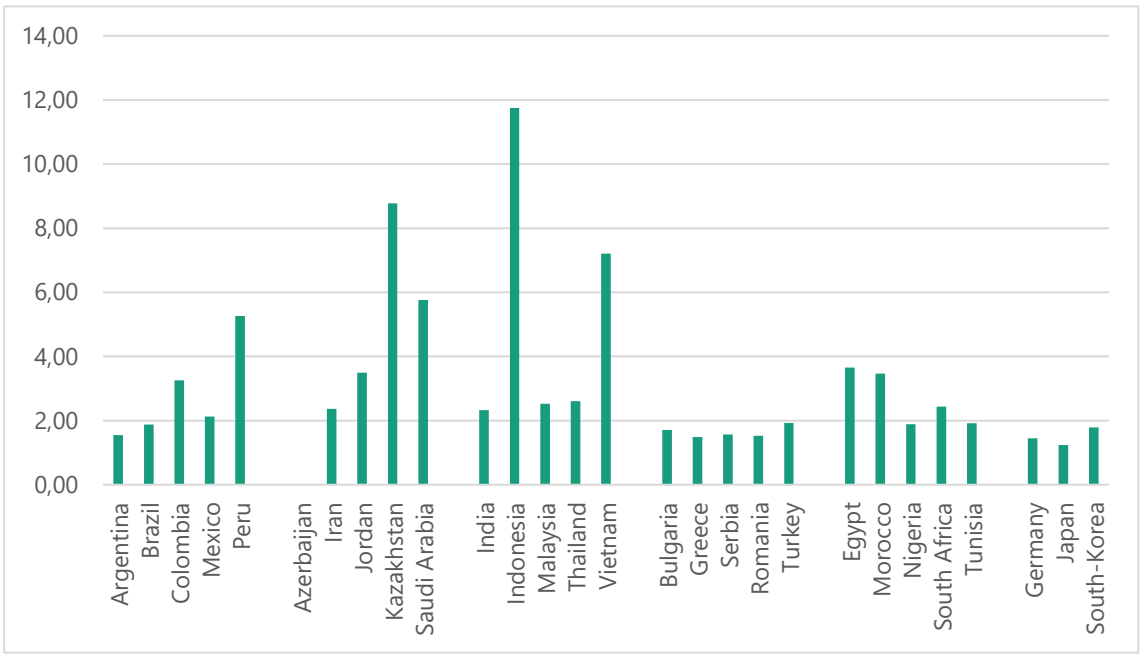
Source: Analysis by Fraunhofer ISI, based on EPO Worldwide Patent Statistical Database (PATSTAT)

Figure A 3: Total Number of Scientific Publications



Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

Figure A 4: Growth of Scientific Publications, 2010-12 vs. 2020-22



Source: Analysis by Fraunhofer ISI, based on Elsevier SCOPUS

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