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Innovation, industrial and trade policies for technological sovereignty

Jürgen Janger
(WIFO)

Interrupted supply chains in the wake of COVID-19 and Russia's attack on Ukraine have highlighted the geopolitical risks of sourcing critical raw materials and products from a small number of authoritarian countries. The EU has initiated a flurry of activities to reduce unilateral dependencies, witnessed by trade, innovation and industrial policy instruments, such as the IPCEIs, the Chips Act and new anti-subsidy measures. This policy brief focuses on fostering technological sovereignty to insure against risks from international trade specifically in critical general purpose technologies. Bundles of innovation, industrial and trade policies enter three consistent policy mixes according to the distance to the technological frontier: for emerging technologies, the frontier policy mix emphasises an improvement in general framework conditions such as a more integrated European capital market. Technologies which lag behind the frontier benefit from coordinated support within the catch-up policy mix, while technologies at risk of losing their position at the frontier fall within the remit of the defensive policy mix.

1. Introduction

Foreign trade and production in international value chains enable the EU and its Member States to achieve a level of economic performance that could never be achieved in autarky, thanks to higher productivity and larger markets. However, the international division of labour is always associated with risks, as COVID-19 and the Russian attack on Ukraine have shown: production stoppages due to suppliers in lock-down and the geopolitical exploitation of one-sided economic dependencies as in the case of Russian gas have led to discussions about the merits of a rule-based international trade regime. The rise of China with its potential control of (chip production in) Taiwan and a possible re-election of Donald Trump as US-president add to the malaise.

In this context, public debates oscillate between a large variety of policy responses, from laissez-faire and a focus on improving horizontal framework conditions to national un-coordinated industrial policies. Driven by large, subsidy-heavy US (CHIPS and IRA acts) and Chinese initiatives, the EU has responded with a flurry of activities, among them the European Chips Act (Dachs 2023).

This policy brief aims at a systematic and evidence-informed discussion of potential policy responses to mitigate risks associated with international trade. The new EU-level concept of "open strategic autonomy" is akin to reducing unilateral dependencies while safeguarding the enormous advantages of an international rules-based economic order.[1] Dependencies may arise if imports of a good are heavily concentrated on few countries and domestic production is lacking, and if no short-term substitution is possible. Such dependencies should however be examined with a view to the capabilities necessary for the production of the goods in question.

A key point of this policy brief is that overall negative trade balances or simple trade deficits in easily substitutable goods should not be a cause for concern: While, e.g., face masks were in short supply at the beginning of the pandemic, their production does not

[1] The three pillars are (Klien et al., 2021, p. 8): resilience and competitiveness to strengthen the EU economy; sustainability and fairness, reflecting the need for the EU to act responsibly and fairly; assertiveness and rules-based cooperation to demonstrate on the one hand the EU's preference for international cooperation and dialogue, but on the other hand also its willingness to fight unfair practices and to use autonomous instruments when necessary to pursue its interests.

entail complex know-how and could easily be scaled up in Europe.

Where unilateral dependencies are a cause for concern is in advanced knowledge-intensive key enabling technologies, or general purpose technologies. On top of supply chain issues or geopolitical exploitation, such dependencies reflect on wider EU deficits in crucial high-tech industries of the future (Cincera & Veugelers, 2013), which constrain EU performance in a wide variety of industries using technologies such as advanced chips or artificial intelligence.

This policy brief suggests that a critical tool for strategic autonomy is fostering "technological sovereignty", or avoiding unilateral economic dependencies in technologies which are both considered critical for further development and could be potentially exploited geopolitically. The effort rests on two pillars, first the necessary capabilities to master and apply these technologies, and/or second, to ensure access to such technologies from a variety of suppliers in EU-friendly countries (Edler et al., 2021; Expertenkommission Forschung und Innovation (EFI), 2022; March & Schieferdecker, 2021). This makes clear that technological sovereignty asks for a mix of innovation, industrial and trade policies. Working against such dependencies is not just relevant to insure against risks from international trade. More fundamentally, it is about safeguarding the general competitiveness of EU industries, addressing key deficits of the EU, already subject of the EU's Lisbon Strategy in 2000.

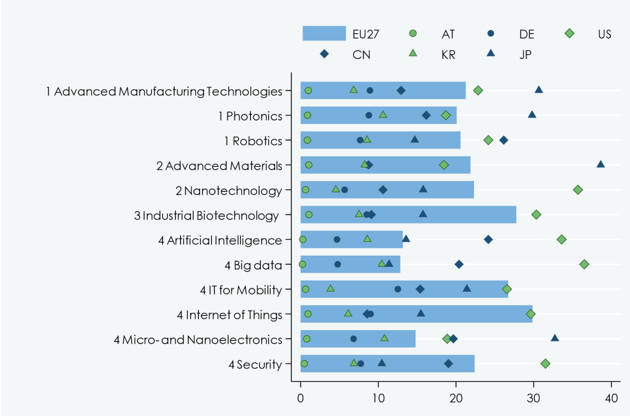
2. EU performance in key enabling technologies

In this chapter we present data from the Patstat database on patented inventions and exports from the BACI database (Gaulier & Zignago, 2010) in 4 broad and 12 detailed key technology areas, called "Advanced Technologies for Industry (ATI)" as identified by Iszak et al. (2021) or Kroll et al. (2022). It is based on a study by Hofmann et al., 2023, which provides a much richer analysis.

The emerging picture of EU strengths and weaknesses should only be seen as a first step towards identifying concerning unilateral dependencies, as it is still at the level of broad statistical classifications rather than "real" individual technologies such as batteries or high-performance chips.[2] It makes the point though that any systematic policy aiming at fostering technological sovereignty will have to take into account varying levels of EU performance which ask for different policy mixes (Chapter 4).

Figure 1 shows the proportions of patent production contributed by major knowledge-producing regions, along with Austria. These patents are granted by the European Patent Office (EPO) or fall under the Patent Cooperation Treaty (PCT). While the EU27 is a significant contributor to technology across various Advanced Technology Industries (ATIs), it generally lags behind the United States, Japan, or China. This indicates that analyses of sovereignty barely make sense at the individual Member State level. Even Germany produces far fewer patents than the EU as a whole. Therefore, for EU Member States, maintaining EU membership is crucial for fostering technological sovereignty, providing full access to technologies developed across all Member States.

Figure 1: Shares of patent applications (EPO/PCT) by inventor per ATI, 2016-2020



Source: PATSTAT Global - 2022 Autumn, Hofmann et al., 2023. Numbers 1-4 refer to the four broad technologies 1 Production, 2 Material, 3 Biotechnology, 4 Digital.

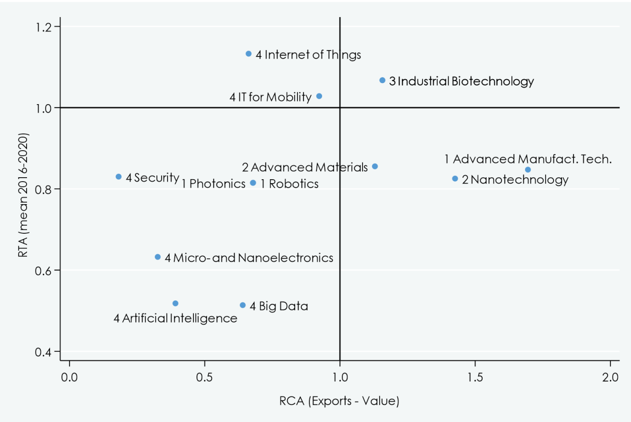
Figure 2 presents a quadrant shaped by two indicators that reveal technological and comparative advantage in ATIs of the EU27. While the first is measured through specialisation in patent production, the second refers to export specialisiation: a share of exports/patents in that technology in total exports/patents of a country higher than the same share at the global level generates a value above 1 which indicates specialisation, and vice versa.

In the upper right quadrant of ATIs, the EU27 demonstrates both inventive and trade specialisation compared to the world average. On the contrary, the lower left quadrant comprises ATIs where the EU27 shows neither inventive nor trade specialisation. Notably, key technologies such as artificial intelligence or micro- and nano-electronics, digital technologies more broadly, are identified as weaknesses for the EU27. This aligns with findings from Kroll et al., 2022. In contrast, biotechnology, and to a lesser extent, advanced manufacturing and production

[2] On top of qualitative product-, firm- or industry-level case studies, the OECD and the newly created Austrian Supply Chain Intelligence Institute (https://ascii.ac.at/) work on methodologies to identify dependencies at a disaggregated level.

technologies, exhibit stronger performance in comparison.

Figure 2: RTA (2016-2020) and RCA (2020) in EU27 ATIs

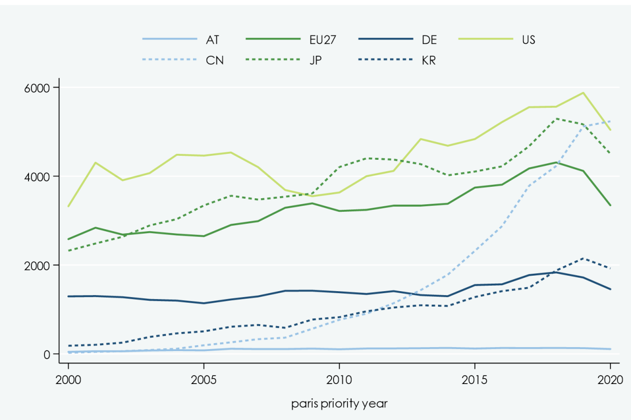


Source: PATSTAT Global - 2022 Autumn, BACI, Hofmann et al., 2023. RTA Revealed Technological Advantage, RCA Revealed Comparative Advantage. Numbers 1-4 refer to the four broad technologies 1 Production, 2 Material, 3 Biotechnology, 4 Digital.

Figure 3 provides an illustration of dynamics in ATIs, in this case for patent production in digital technologies. Since 2005, China has seen tremendous growth of patents filed in digital technologies, overtaking the EU, Japan and even the US in the last available year 2020 (declining numbers in 2020 should be interpreted with caution, as patent data are usually revised backwards). Should this trend continue along similar lines, China would soon be the undisputed leader in inventions related to digital technologies.

These dynamics, together with the insights from the pandemic and Russia's attack on Ukraine, are the backdrop for a large variety of innovation, trade and industrial policies briefly discussed in the next chapter.

Figure 3: Number of patent applications (EPO/PCT) in digital technologies, 2000-2020



Source: PATSTAT Global - 2022 Autumn, Hofmann et al., 2023.

3. Recent policy responses bearing on technological sovereignty

China combines industrial and innovation policies to develop domestic technologies and reduce reliance on foreign imports. Initiatives like the Strategic Emerging Industries Program, beginning in 2006, enforced compulsory sharing of technological know-how in joint ventures for market access in China (Felbermayr et al., 2022). The Made in China 2025 initiative targets 10 key industries, aiming for global leadership with regulatory support, substantial subsidies, and affordable loans, notably investing 200 bn US$ in chips alone.

Whereas the US under President Trump started to use trade policies to contain China, President Biden has launched two major packages, the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act (Dachs, 2023) and the Inflation Reduction Act (IRA) (Kleimann et al., 2023), with particularly the first one relevant for technological sovereignty. It contains a mix of instruments, such as innovation (R&D subsidies), industrial (investment subsidies) and trade policies (export restrictions on advanced goods destined for China). Neither subsidies in the US nor in China are being examined for their effect on competition, as has to be done in the EU following state aid rules aimed at safeguarding a proper functioning of the Single Market.

However, according to recently reported data (Johnston et al., 2023), state aid by EU Member States also tremendously increased from 103 bn € in 2015 to 733 bn € between March 2022 and August 2023. How much of this is relevant for technological sovereignty is however unclear. At the EU-level, a variety of instruments and policies have been put in place. As an example, the EU has undertaken a monitoring of products with possible strategic dependencies.[3] Furthermore, the European Chips Act (Dachs, 2023) contains both innovation (R&D subsidies of 11 bn €) and industrial (investment subsidies, to be delivered by the Member Sates) policy instruments.

An initiative with particular relevance for establishing technological sovereignty are the Important Projects of

[3] Monitoring results can be found on https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy/depth-reviews-strategic-areas-europes-interests_en (accessed 3.11.2023)

Common European Interest (IPCEIs)[4] which are aimed at fostering research and first industrial deployment across the whole value chain in areas such as batteries or microelectronics. Austria participates in several of these IPCEIs and has some homegrown relevant initiatives, such as the Silicon Alps Cluster for electronics. Most of Austrian R&D support is however bottom-up, non-targeted, both in basic as well as in applied research (Janger, 2022).

Coming back to the EU-level, the Critical Raw Materials Act (Hool et al., 2023) addresses the lack of secure access to critical raw materials such as rare earths needed for electric mobility through a combination of several instruments. Moreover, the EU has given itself a range of new trade policy instruments such as the anti-subsidy instrument, or the Foreign Direct Investment (FDI) screening instrument, to counter anti-competitive subsidies and protect sensitive know-how from being sold to non-EU countries (Felbermayr et al., 2022).

This list of EU and national policies relevant for technological sovereignty is not exhaustive, there are many other relevant instruments, such as relevant calls in the collaborative Horizon Europe programmes. Setting aside criticisms of insufficient budgetary size given the support packages of the US or China (for the Chips Act, e.g., Dachs, 2023), the intensity of the policy response at EU level bearing on technological sovereignty has certainly been high.

However, so far, the EU lacks a systematic approach that outlines coordinated policies for innovation, industry, and trade in key technologies. This approach should consider how advanced the EU is compared to leading nations ('distance to the frontier') and draw on the experiences of countries that successfully advanced in key technologies from less advanced positions. This policy brief suggests such an approach in the next chapter.

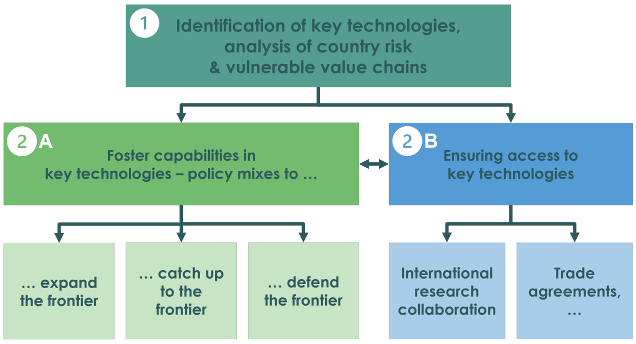
4. Policy mixes to foster technological sovereignty

Figure 4 illustrates a stylized approach to foster technological sovereignty. The first step in promoting technological sovereignty is a constantly updated assessment of which technologies can be considered key enabling technologies, or ATI. The identification requires, among other things, technological foresight analyses (e.g. Edler et al., 2021). The German EFI (2022) calls for the key technology status to be assigned only on the basis of transparent criteria and for an independent advisory body to decide on this in order to prevent abuse by protectionist special interests. Analyses to determine the EU27 performance in these technologies, as well as any country risks (a one-sided dependence on Norway or Australia is to be assessed differently than one on Russia) and sensitive value chains, are best carried out at EU level. The EU has set up a portal[5] for the first purpose, which unfortunately is not updated regularly and only provides information on EU countries.

In the second step, two mutually supporting measures can be taken. First, ensure or expand international access to key technologies, e.g. via trade agreements or international research collaborations with countries sharing the EU's values. Second, own capabilities can be developed. It is well known that the effectiveness of economic policies may vary with the distance to the technological frontier of the treated units (Acemoglu et al., 2006; Aghion & Howitt, 2006). Hölzl & Janger (2014) empirically show that firms in countries far from the frontier perceive different barriers to innovation than those in countries close to the frontier. Whereas in the former, financial barriers are usually perceived as the main obstacle, in the latter, a shortage of skilled labour force is most frequently cited as a barrier to innovation.

We suggest categorizing policies based on the distance of each technology from the worldwide technological frontier. The proposed policy mix comprises three groups. The first addresses key technologies already at the frontier in the EU, or emerging ones. The second focuses on technologies where the EU needs to catch up to the frontier. The third deals with technologies where the EU's position at the frontier is endangered.

Figure 4: Fostering technological sovereignty



Source: Author.

4.1 The frontier policy mix

The frontier policy mix is not just relevant for the key technologies where the EU holds a frontier position identified in chapter 2, but for all emerging technologies which are in a similar nascent state around the world.

The main element in this mix is the full arsenal of research and innovation policies, from fostering pure

[4] For IPCEIs, see https://competition-policy.ec.europa.eu/state-aid/legislation/modernisation/ipcei/approved-ipceis_en (accessed 2.11.2023)

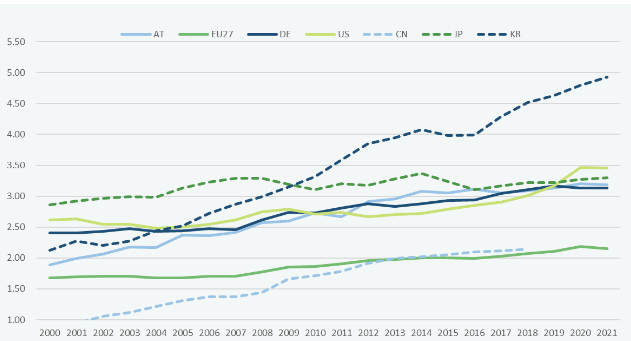
[5] Information on ATIs can be found here https://ati.ec.europa.eu/ (accessed 25.10.2023)

and use-inspired basic research through the European Research Council (ERC) or collaborative Horizon Europe projects to scaling-up of start-ups e.g. through the open accelerator programme of the European Innovation Council (EIC). Although the ERC supports engineering projects, there appears to be a gap in the EU-level Research and Innovation (R&I) policy framework. Specifically, there are no large technology-oriented funding programs that operate in a bottom-up manner, meaning that they do not exclusively focus on specific technologies or fields of research.[6] The EIC could assume this role, however its budget (1.6 bn € in 2023) is currently very small, amounting to roughly 1,5% of EU-level R&D support or 0.001% of EU GDP.

In principle, policies may not need to be targeted to specific technologies, as frontier projects or firms will be naturally selected by non-targeted horizontal EU-level and national policy instruments which screen for the best available proposals. As an example, the Dutch maker of chip production machines ASML will not find it difficult to obtain funding. In practice, once emerging technologies are found to be potentially important general purpose technologies, a more targeted approach (e.g. within the collaborative framework EU programme, which has always funded "top-down", but also within the EIC which features "top-down" schemes as well) may accelerate the development of the technology and ensure EU competitiveness.

Further key for the frontier policy mix are general framework conditions for innovative activities. This is an area where the EU is showing big deficits. Taking R&D investments as a percentage of GDP as a general indicator of the conduciveness of framework conditions for innovative activities, Figure 5 illustrates that something must hold them back in the EU. R&D investments increase only slowly in the EU, by contrast with Korea, the US and China, which has overtaken the EU in 2014.

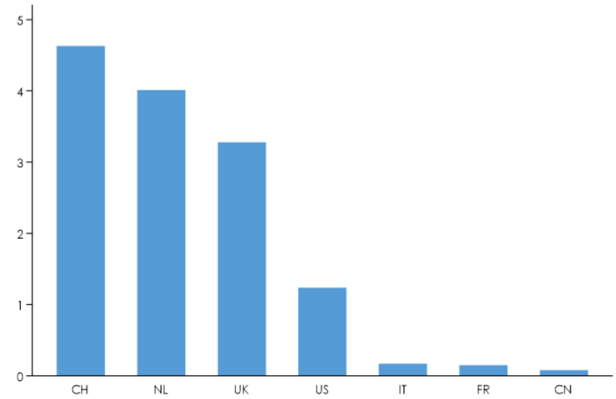
Figure 5: R&D as a % of GDP, 2000-2021



Source: OECD MSTI.

Low R&D investments are partly due to a lack of young innovative information technology or other tech firms which have turned out to be new industry leaders in the US, but also in China (Moncada-Paternò-Castello & Grassano, 2022).[7] Among relevant factors to explain this lack is university research performance (Van Looy et al., 2011). In the EU, only the Netherlands count a significant number of top research performing universities, whereas the large EU countries have few to no top research universities (Figure 6). This in turn is partly due to enormous differences in university expenditures, with universities such as the ETH Zurich or Imperial College London spending two to three times as much per student than technological universities in Germany, Austria and other EU countries (Hofmann & Janger, 2023).

Figure 6: Number of universities per 10 million population in the global top 100 (share of top-cited articles)



Source: CWTS Leiden Ranking.

Another main determinant of lacklustre dynamics of innovative firms is a fragmented European capital market (Kleimann et al., 2023), making it challenging for start-ups to scale up. Reforms towards a capital market union would be a main horizontal "industrial" policy in the frontier policy mix, i.e. an industrial policy that is not a priori targeting specific firms or industries. Integrated capital markets would perform better at channelling funding towards all types of innovative firms.

Trade policies can foster international trade agreements with "safe" countries to diversify supply routes. Given the complexity of advanced technologies for industry, the range of relevant potential trade agreements will however be limited to countries which are able to master at least parts of the global value chains involved. Examples are the EU-South Korea Free Trade Agreement, or the EU-Japan

[6] The US Chips Act has added a technology directorate to the National Science Foundation (https://new.nsf.gov/tip/latest, accessed 2.11.2023), the main federal funding agency in the US outside the life sciences.

[7] Microsoft and Apple were founded in the mid-1970s, Google in the late 1990s, similar to the Chinese battery manufacturer BYD; Huawei was founded in 1987, the dominant Chinese battery manufacturer CATL as recently as in 2011.

Economic Partnership Agreement.[8] These two agreements have been concluded before the recent shocks outlined in the introduction. They could hence be screened for improvements with respect to advanced technologies for industry, which is beyond the scope of this policy brief.

In addition to pure trade agreements, international collaboration initiatives can boost exchange of best practices, research and skill-building efforts. A recent example is the signing of the EU-India Memorandum of Understanding on semiconductors.[9]

In a nutshell (Figure 7), the stylized frontier policy consists of (much) more of the same, (non-targeted) R&D support, possibly with an increased focus on engineering, reforms to framework conditions and pro-active trade policies. Note that R&D also plays a role for catching-up, by increasing the absorptive capacity of firms for new knowledge (Griffith et al., 2004), and that favourable framework conditions are relevant for catch-up too. Deficits in this policy mix may be seen as a key factor explaining why the EU lags behind the frontier in important critical key technologies.

4.2 The catch-up policy mix

Catching up to the frontier in specific key technologies asks for a different mix of policies than expanding the frontier (Figure 7). Regarding R&I instruments, there is a rich literature on countries which were behind in specific technologies and undertook focused and co-ordinated efforts to catch up in a speedy manner to the frontier. As the frontier and its technological performance characteristics are known, instruments can be much more targeted.

There are several options available to the EU. The fastest one would be to incentivise EU-based production by foreign firms which are at the frontier of the key technologies, not building capabilities through own R&D but importing them through industrial policies. This is specifically done in the European Chips Act, which provides a legal framework for state aid for chip production facilities. An example of foreign investment in a key technology area is the planned establishment of an Intel plant in Germany, incentivised with a high subsidy of about 10 bn € yet to be granted by the EU. It remains to be seen if this will solve the EU's lagging behind the frontier. FDI may only boost vertical knowledge spillovers, but not horizontal ones (Harrison & Rodríguez-Clare, 2010), which would be necessary to foster chip production in the EU more generally and not to remain dependent on Intel's continued presence in Germany.[10] Harding et al. (2019) are more positive, particularly in the case of FDI in countries behind the frontier set to benefit from spillovers.

A second option is the creation of dedicated agencies which co-ordinate and fund the R&I catch-up effort in the form of technology-specific R&D funding programmes. Existing EU instruments such as the IPCEIs could easily fit into such a co-ordinative umbrella, although they are currently not framed as catch-up instruments, along with other instruments: the EU has yet to adopt a focused catch-up perspective, clearly acknowledging the distance to the frontier and specifying policies to catch up.

A modern example for a successful research funding agency which sets specific technological performance goals and actively co-ordinates research efforts to reach them is the Advanced Research Projects Agency (ARPA) of the US (Azoulay et al., 2018; Bonvillian, 2018; Gross et al., 2022; Tollefson, 2021). While used in the US to sponsor breakthrough research for national security, ARPA's operational approach could be considered for catching up to the frontier. The EU's EIC Pathfinder Challenge Scheme shares some features, like highly-qualified and autonomous program managers, but mostly lacks specific technological goals, is not designed as a catch-up instrument and does not focus on advanced technologies for industry only, not to mention its small budget (chapter 4.1).

A second modern example for a focused effort to rapidly develop new technologies are the COVID-19 research programmes, in particular Operation Warp Speed in the US to develop vaccines (Gross & Sampat, 2022). Further historic examples are the Office of Scientific Research and Development (OSRD), which organised the US' World War II military research effort (Gross & Sampat, 2023). It set research priorities and identified suitable research institutions and firms, which could perform the research, as well as connecting research to pilot and ultimately mass production. Like ARPA, OSRD bypassed proposals as a tool to select among a range of competing projects. It went directly to research performers, facilitated by its highly qualified scientists on staff, saving considerable time. In many of the research areas, there was anyway only a handful of candidates, similar to modern settings e.g. with chip production machines, where there is basically one firm in the EU (ASML).

Both OSRD and ARPA co-ordinate(d) different technologies. NASA is a dedicated agency for space technologies and another example for how the US caught up to the frontier after the Sputnik shock, overtaking Russia and landing a man on the moon (Kantor & Whalley, 2023). At the peak of the space

[8] A full list of EU trade or economic partnership agreements can be found here https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/negotiations-and-agreements_en (accessed 27.11.2023)

[9] The Memorandum can be found here https://digital-strategy.ec.europa.eu/en/library/memorandum-understanding-semiconductors-india (accessed 27.11.2023).

[10] Tesla refused possible IPCEI subsidies of 1,1 bn € for its gigafactory in Germany for fear of having to share battery technology (https://www.handelsblatt.com/unternehmen/industrie/tesla-sorge-um-batteriegeheimnisse-darum-verzichtet-tesla-auf-milliardenschwere-staatshilfe/27837626.html, accessed 24.10.2023)

race, NASA's budget was 0.7% of GDP. In comparison, Horizon Europe amounts to just approx. 0.1% of EU GDP.

All these agencies co-ordinate(d) funding for research performed de-centralised in research institutions, universities and firms. Yet another way though, in particular suitable when transfers of complex knowledge and skills ask for close personal interaction, can be a central research institution which performs the research inhouse (Gross et al., 2022). An example in the US was the MIT radiation laboratory, again during the Second World War, which led to numerous private spin-offs, and in fact the creation of a new industry. While many extra-university research institutions exist in the EU, there are none so far with explicit catch-up tasks.

Focused, targeted R&D is generally best funded at the EU-level, where projects and firms from all over Europe can be selected. A larger pool of potential research performers was always a functional argument in favour of EU-level R&D support (Mitsos et al., 2012), but with respect to critical technologies in which the EU is lagging behind, the argument is even stronger: in general, few relevant advanced research institutions exist throughout the EU in these technologies. More EU-level R&D support asks for a significant increase of research funding at the EU-level. Adding 0.6% of GDP to EU-level R&D funding – the difference from current levels to space-race NASA levels – without cutting Member State R&D would place the EU's R&D intensity at 2.8% of GDP, still far lower than the US' 3.5%.

Another option are bilateral development programmes, as e.g. after the Second World War in form of the Marshall plan. This plan included the US Technical Assistance and Productivity Program, which provided training for European managers in the US and sent US machines to factories in Europe, with significant long-run positive effects on productivity (Giorcelli, 2019). While some may balk at the perspective of treating the EU as a region to be developed, the significant performance lags in some key technologies and the urgency of the geopolitical situation[11] are factors which should drive the adoption of the most effective way for catching up to the frontier. Heeding lessons from former developing countries such as the US (with respect to Britain, Cohen & DeLong, 2016) and South Korea (Lane, 2022), and how they managed to catch up to the frontier and overtake the EU, should not be dismissed a priori.[12] With a view to fostering horizontal spillovers and given the substantial security benefits also for the US if the EU catches up to the frontier, new programmes could be devised, which encourage technology transfer in key digital technologies such as chip production or artificial intelligence.

Industry and trade policies may play particular roles if start-ups or firms start production in areas where they face superior competition from abroad. Many of the key technologies mentioned exhibit dynamic economies of scale linked to learning-by-doing, so that firms which enjoy a headstart in scaling up production expand their competitive advantage, making it harder for newcomers to catch up in spite of lower R&D costs. Such economies of scale are a classic argument for infant-industry protection (Harrison & Rodríguez-Clare, 2010; Melitz, 2005) widely practiced (in the past) by many countries such as China, the US, South Korea and arguably the EU in the case of Airbus.

Several recent empirical studies show that a temporary protection of nascent industries before they become fully competitive can work (e.g., Hanlon, 2020; Juhász, 2018; Juhász et al., 2023). De facto, such protection is possible in the EU in the form of state-aid, or subsidies for investment and production. Subsidies lower costs and hence make firms more competitive. Trade policies, such as tariffs increase prices of foreign competitors, making them (but potentially also downstream industries in the EU) less competitive. In the EU context, pro-actively using tariffs to protect infant industries is potentially riskier than subsidies, as other countries can retaliate, unless they can be motivated by similar subsidies in the past in non-EU countries. Many technologies or industries receive massive state subsidies in China, which uses them to reduce foreign competition and then dominate a market (e.g., in shipbuilding Kalouptsidi, 2018, or in magnesium Friesenbichler & Klimek, 2023).

The use of such trade instruments should be carefully evaluated and the WTO rules respected. Some analysts think however that catching up, e.g. with the Chinese battery firm CATL, will not work without some form of trade barrier (McMorrow et al., 2023). Protection on its own is unlikely to work, as it does not overcome co-ordination failures between the actors involved, calling for their use in a consistent policy mix (Harrison & Rodríguez-Clare, 2010).

Also note that some arguments against targeted industrial policies are less relevant in the case of well-identified key technologies. A main problem of such policies is that it is difficult to pick the right sector which is supposed to be developed for the benefit of wider economic growth and jobs. Critical technologies in which the EU is lagging don't need to be picked, they can be empirically identified (introduction to chapter 4). The target of the catch-up policy mix is to support reaching a well-defined technological performance characteristic not for the sake of jobs per se, but for safeguarding the technological sovereignty of the EU.

[11] US intelligence apparently thinks that a Chinese attack on Taiwan is likely by 2027 (Rachman, 2023).

[12] South Korea embarked on focused catch-up in the wake of the announcement of US withdrawal in the 70ies, for fear of inferior industrial capabilities with respect to North Korea (Lane, 2022).

4.3 The defensive policy mix

The defensive policy mix applies to technologies where the EU is in danger of losing its frontier position, or has only recently fallen behind the frontier. Two cases are relevant. One is protecting know-how from theft, e.g. through cybersecurity meaures. Trade policies can jump into action when frontier research is threatened by unfair subsidy practices abroad, e.g. via the new "anti-subsidy" instrument (Felbermayr et al., 2022). Related to this, the new FDI-screening instrument can investigate purchases of start-ups or firms if there is a danger that frontier knowledge may be lost and exploited strategically by countries posing potential security threats. However, the tool has been assessed so far as being weak (Braw, 2019). This is a good example of a change in policy nevertheless, from "blind" commitment to international trade and FDI to an approach which actively manages potential risks, taking into account the geopolitical dimension. Screening of research collaborations or FDI can also happen in the opposite direction, if e.g. EU firms with capabilites in critical technologies engage in potentially risky or unfair knowledge-sharing agreements.

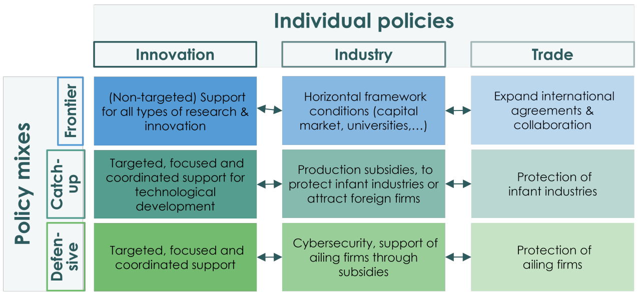
The second case is a threat of irretrievable losses of critical skills in key technologies due to failing companies without alternative EU-based suppliers, or at least suppliers in "friendly" non-EU countries. Here, particularly sensitive issues arise for the economic policy of the EU27. Such a scenario is feared, for example, for 5G and 6G technologies in mobile communications, where Huawei is both technologically superior and cheaper. Before COVID-19 and Russia's attack on Ukraine, these companies would probably also have been allowed to fail, following the EU's - despite Airbus - industrial policy experience of "picking the winners", often practised as "defending the losers" (Polt et al., 2021).

Today, there could at least be an examination based on transparent evidence and criteria as to whether such a failure would not result in an irretrievable loss of critical capabilities, or a sharp increase in one-sided economic dependence on politically sensitive countries. Depending on the outcome of such an assessment, either the company could be sent into bankruptcy, or an exemption from EU state aid law could be examined as well as measures on how the company - or relevant parts of it, especially its key competences - could be made competitive again. Temporary infant industry protection instruments have already been discussed in the section on catching up, targeted R&I support would also be a natural option.

It is questionable though if such a situation can be solved by applying a standardised policy mix. Nevertheless, a start should be made now at the European level to develop contingency procedures, regardless of whether they will ever be used or not. This would also be an element of strengthening the EU's resilience in crises.

In any case, it is better to proactively prevent the emergence of critical one-sided dependencies in the first place. This requires essentially a well-working frontier policy mix, that is sound R&I support, competitive (higher) education systems, a functioning European Single market – including a yet-to-be achieved capital market union – and further attractive framework conditions for the rapid growth of innovative start-ups.

Figure 7: Innovation, industrial and trade policies in three policy mixes



Source: Author.

5. Conclusions

In a nutshell, international production has always been associated with risks as it can result in unilateral dependencies that nations exploit geopolitically, or that lead to large economic losses because of interruptions to production. Dependencies emerge when goods lack substitutes or alternate supply sources from other countries.

It is important to note that they should not call into question the significant benefits of international trade, which usually outweigh the associated risks. If domestic production or a diversification to alternative suppliers is possible in the short term, e.g. if the goods involved do not require advanced knoweldge, dependencies can quickly change.

One area where such risks should be managed more pro-actively however is in key enabling technologies, general purpose technologies which are relevant for large parts of the EU economy. Being able to master and use such technologies defines the concept of technological sovereignty. It extends beyond safeguarding against risks arising from international trade to encompass broader perspectives on economic development.

Several policies have been initiated by both the EU and its Member States to bolster technological sovereignty, including the European Chips Act, IPCEIs, and significant state aid directed towards attracting pertinent foreign firms. However, a coherent and comprehensive intervention framework designed to actively nurture technological sovereignty has been lacking. This policy brief suggests to bundle innovation, industrial and trade policies by the distance of the EU performance level to the global technological frontier.

We distinguish three policy mixes, the frontier, catch-up and defensive policy mix. All crucially rely on the identification of key critical technologies based on transparent criteria by an independent expert panel. All benefit from the advantages of a large integrated market as is the EU – each individual Member State would be too small to master all critical technologies. EU Membership is the most effective way for any Member State to secure access to a wide range of critical technological know-how.

Regarding the frontier policy mix, expanding the frontier asks for higher, not necessarily targeted R&D expenditures, pro-active trade policies and improved framework conditions: Fragmented EU capital markets and insufficiently resourced universities are a drag on the EU's innovation performance. Deficits in this frontier policy mix are a main reason why the EU is lagging behind in key critical technologies.

Catching up in them needs a focused, targeted and co-ordinated R&D effort, as well as support to nascent industries by industrial and trade policies to scale up production. There a many international examples from the past illustrating how countries such as the US or South Korea which were originally behind the frontier have successfully caught up to it, using a variety of focused and co-ordinated approaches. They could inspire a catch-up policy mix for the EU. So far, it has however not adopted a clear catch-up mindset, which would ask for explicitly acknowledging any gap to the frontier in critical technologies and specifying goals, instruments, co-ordinating agencies, etc., with a view to catching up. Performance lags in key technologies and the urgency of the geopolitical situation are factors which should drive the adoption of the most effective way for catching up to the frontier.

Defending it, e.g. saving critical competencies in failing firms, asks for an evidence-informed, transparent ex-ante procedure to determine the risks to technological sovereignty, coupled with supportive R&D, industrial and trade policies. R&D and production subsidies should always be transparent.

Key in all mixes is EU membership, which provides a natural wide selection of like-minded and safe trading partners. Even the largest individual EU nations face limitations in achieving technological sovereignty independently due to the dispersion of key research institutions and firms across the EU. In principle, all R&D and innovation support for critical technologies could be "Europeanised". Consequently, all policy mixes emphasize the necessity for substantially augmented funding at the EU level for R&D programmes, capitalizing on a larger and more comprehensive pool of pertinent research contributors. At the peak of the space race, when the US undertook a focused effort to overtake Russia in the wake of the Sputnik shock, NASA's budget was 0.7% of GDP, compared with 0.1% of GDP for the EU's Horizon Europe programme.

Unfortunately, the EU has been lagging behind in the development of several key technologies, in particular digital technologies such as micro-electronics and artificial intelligence. While the US is racing ahead, China is overtaking the EU. At the EU level, it appears that Mario Draghi will be tasked with a report to "regain the EU's competitive edge" (Johnston et al., 2023). This policy brief contributes to this debate with a specific focus on how to foster technological sovereignty, i.e. being able to master and apply critical general purpose technologies. Addressing this challenge may require unconventional approaches, which, despite appearing unorthodox to some, are firmly rooted in empirical economic research and supported by successful real-world best practices. Experimentation with such approaches is encouraged as a means to tackle this pressing challenge and reduce unilateral dependencies in critical general purpose technologies, which may be exploited geopolitically.

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Author:
Jürgen Janger
WIFO (Austrian Institute of Economic Research)
E-mail: juergen.janger@wifo.ac.at

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Contact:
FIW project office
c/o WIFO
Arsenal, Object 20
1030 Vienna
Phone: +43 1 728 26 01 / 335
E-mail: fiw-pb@fiw.at
Website: https://www.fiw.ac.at