Reverse Dependencies on China: How Europe Can Remain Technologically Indispensable and Preserve its Strategic Autonomy

Jan-Peter Kleinhans and Tim Rühlig

ABSTRACT

In adapting to growing geopolitical competition over digital technology, the European Union and the United Kingdom are striving for economic security and technological sovereignty. European policies focus on reducing critical (over-)dependencies on China. However, technological ecosystems are deeply transnational and a full decoupling would result in a situation where Europe had no leverage. China's technological advancement continues to rely on the outside world, including Europe. Under these circumstances, Europe should complement its current policy with policies that help to maintain reverse dependencies and help it to remain technologically indispensable to China. In 12 concrete cases, this report assesses Europe's technological strengths and the potential leverage they might give it. Europe should calibrate its levels of ambition technology by technology across four levels: threat prevention, ability to deny, ability to act and curtailment. Not every European technological strength has the same degree of political leverage, as for example levels of substitutability and spillover damage diverge. Strengthening European security will require a balance of strategic entanglement with China and autonomy, and a combination of "promote", "protect" and "partner" tools. This chapter discusses policy patterns across technologies; but Europe will need to tailor its tools to the specific characteristics of individual technology ecosystems.

The geopolitical contestation over disruptive technologies between the United States (US) and the People's Republic of China (PRC) leaves a deep imprint on Europe.[1] Policymakers in the European Union (EU) and the United Kingdom (UK) are concerned that technological (over-)dependencies could constrain the policy choices at their disposal. Europe's reliance on Chinese technologies is a particular subject of concern.[2]

The digital technological footprint of the PRC is rapidly growing. China's party state-permeated economy has created favourable conditions for a further increase in the global market share of Chinese technology companies.[3] This undermines the competitiveness of European firms. The assumption that an authoritarian country such as China is incapable of ground-breaking innovation has turned out to be an illusion.[4] On the contrary, China has been able to subtly spread the authoritarian values inscribed in its digital technologies across the globe.[5] This goes against Europe's stated core interests. No European state is in a security alliance with the PRC and Europe and China could find themselves on

1 We would like to thank James Beioley, Hanna Dohmen and Hanna Zinner for their comments on a previous version of this paper. In this report, "Europe" is defined as the European Union (EU-27) and the United Kingdom (UK) unless otherwise stated.

2 Government of the UK, *Global Britain in a Competitive Age: The Integrated Review of Security, Defence, Development and Foreign Policy*, London, 2021, accessed 29 October 2023, at https://assets.publishing.service.gov.uk/media/60644e4bd3bf7f0c91eababd/Global_Britain_in_a_Competitive_Age-_the_Integrated_Review_of_Security__Defence__Development_and_Foreign_Policy.pdf; and European Commission, Joint Communication to the European Parliament, the European Council and the Council on "European Economic Security Strategy". JOIN/2023/20 final, Brussels, 2023, accessed 29 October 2023, at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023JC0020&qid=1687525961309.

3 Tim Rühlig (ed.), *China's Digital Power: Assessing the Implications for the EU*, Berlin, Digital Power China, 2022, accessed 29 October 2023, at https://dgap.org/en/research/publications/chinas-digital-power

4 Tim Rühlig, "The Roots of China's Innovativeness: Why China's Unstoppable Innovation Powerhouse Might Falter," *DGAP Analysis* no. 5, Berlin, DGAP, 2023.

5 Paul Scharre, "The Dangers of the Global Spread of China's Digital Authoritarianism", Testimony before the US-China Economic and Security Review Commission, Hearing on "Rule by Law: China's Increasingly Global Legal Reach", 4 May 2023, Washington, DC, Center for a New American Security, 2023, accessed 29 October 2023, at https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/Paul_Scharre_Testimony.pdf

opposing sides of an escalating conflict. The friendship between Russia and China may not be as "limitless" as proclaimed,[6] but China's technological development could pose a direct security threat to Europe if the PRC decided to share parts of its dual-use know-how with Russia. Many fear that the possibility of the PRC leveraging its technological dependencies against Europe could constrain the strategic choices of the EU and the UK.

In response, Europe is aiming for a reduction in risk. Several policy instruments have been put in place to this end, such as the EU's investment screening mechanism or the 5G Toolbox. Other policy tools are still in the process of adoption, such as the Critical Raw Materials Act proposed by the European Commission. Most prominently, the EU has launched an European Economic Security Strategy (EESS) that it is now implementing. The Commission published the first implementation package in January 2024.[7] It outlines next steps, some of which have already begun, such as risk assessments of four critical technologies. Similarly, the UK's Integrated Review prioritises innovation in critical technologies such as artificial intelligence (AI), quantum computing, engineering biology, nuclear technology, cyber and space. Technological strength in these fields is seen not only as vital to the UK's future prosperity, but as a precondition for remaining resilient in a world shaped by the utilisation of dependencies in an intensifying power competition.[8] Consequently, the UK has tightened its own investment screening, to name just one of several policy instruments.[9]

Most of these instruments are reactive and protective in nature. Europe is striving to address its technological weaknesses and reduce its over-dependencies on technologies and raw materials that are considered critical. Such de-risking is certainly a necessary process of adaptation to the new geopolitical realities, especially if Europe can successfully differentiate between diverging risk profiles across several emerging and foundational technologies and adopt policy instruments that meet these specific profiles. In its previous report, the Digital Power China (DPC) research consortium proposed such a risk classification, assessed eight emerging and foundational technologies, and made concrete policy recommendations for Europe.[10]

However, what the current de-risking policies neglect is that it is virtually impossible to reduce strategic dependencies to a degree that provides the economic security and technological sovereignty the EU and the UK are seeking. The cost of such decoupling would be enormous and, for good reason, nobody is realistically willing to pay such a high price. The development and production of most emerging and foundational technologies – we speak of "technological ecosystems" – are based on a highly transnational division of labour. All actors are likely to remain interdependent for the foreseeable future. Technological decoupling is impossible and explicitly not desired – by either the EU or the UK.

However, if technological self-reliance is neither feasible nor Europe's goal, Europe will need to remain technologically indispensable in order to be a strategic actor in global supply chains. In other words, under conditions of persistent interdependence, Europe can only prevent being constrained by technological dependencies if it pursues two complementary strategies at the same time: reducing strategic dependencies on China where possible and ensuring that it remains technologically *indispensable* to China. Each technological ecosystem requires a different mix of policies that aims for "autonomy" or "strategic entanglement". However, reverse dependencies on China should be factored into Europe's policies more prominently. Europe will preserve its sovereignty if the PRC leadership considers the cost of going against the EU's and the UK's core interests to be too high.

It might be argued that the logic of interdependence has not prevented Russia from violating international law and attacking Ukraine. Indeed, a high technological and economic cost for China is no guarantee that the PRC will not go against European core interests, which is why Europe must reduce its strategic dependencies on China, as it is currently doing. Studies have demonstrated

6 President of Russia, Joint Statement of the Russian Federation and the People's Republic of China on the International Relations Entering a New Era and the Global Sustainable Development, Moscow, the Kremlin, 2022, accessed 3 March 2024, at http://www.en.kremlin.ru/supplement/5770

7 European Commission, "Commission Proposes New Initiatives to Strengthen Economic Security", Press release, accessed 14 April 2024, at https://ec.europa.eu/commission/presscorner/detail/en/IP_24_363

8 Government of the UK, op. cit.

9 Government of the UK, "National Security and Investment Act 2021", accessed 29 October 2023, at https://www.legislation.gov.uk/ukpga/2021/25/contents/enacted

10 Tim Rühlig (ed.), *Europe's Strategic Technology Autonomy From China: Assessing Foundational and Emerging Technologies*, Berlin, Digital Power China, 2023, accessed October 28 2023, at https://dgap.org/en/research/publications/europes-strategic-technology-autonomy-china

that the economic costs of decoupling were higher for Russia before the war than they would be for China now.[11] However, in the absence of a feasible decoupling strategy, maintaining a high cost for China is the best of all imperfect policy options to complement – rather than replace – efforts to reduce strategic dependencies. The fact that Russia has acted irrationally is no evidence that China will do the same. The PRC is in the middle of a structural economic transformation and economic growth is still considered vital for the legitimacy of the rule of the Chinese Communist Party (CCP). Security considerations gain in importance relative to economic development, but this does not mean that the Chinese leadership does not consider a further deterioration in economic growth to be a threat to its power. In other words, while no guarantee, imposing economic and technological costs still has a fair chance of shaping the considerations of the CCP leadership.

Preserving European technological strengths sounds more trivial than it is, as such a policy will require a shift in perspective. It is not weaknesses alone that should be at the centre of our considerations, but also how to preserve technological strengths and maintain technological leadership.

UNDERSTANDING EUROPEAN STRENGTHS

Against most expectations, the PRC has developed into an innovation powerhouse.[12] Recent Australian research has found that China leads in 37 of 44 critical technologies, as measured by international research output.[13] The latest Cyber Power Index prepared by the Belfer Center ranks China second, falling short only of the cyber capabilities of the United States.[14] The World Intellectual Property Organisation's Global Innovation Index paints a slightly different picture: China is placed 11th, but still ahead of several industrialised economies including France.[15] These and other similar studies might be unable to grasp the full complexity and degree of China's technological advance. While only approximations, however, all these reports paint a clear picture: the PRC, through its universities, research institutes and companies, can be highly innovative.

China's emergence as a technological power presents Europe with a reality it did not anticipate. For decades, European policymakers ascribed western digital prowess to the beneficial combination of liberal democracy and free market capitalism. As a non-democratic, non-free-market state, China was believed to be unable to emulate this success.[16] This interpretation has turned out to be false. China has gone far beyond catching up with the West. The fundamental "sin" driving the PRC's growth model – the theft of intellectual property (IP) – cannot account for why China has overtaken the West in several emerging and foundational technologies. If IP theft alone had been the sole characteristic of the China model, the PRC would have run out of steam as China gained technological leadership.

As is argued in more detail elsewhere, China's formula for success comprises "Five Virtues": (a) a skilful modulation of protectionism in a large market; (b) attracting knowledge into the country; (c) liaison with western actors; (d) party-state guidance instead of control; and (e) domestic competition with Chinese characteristics. However, all these virtues are being challenged by domestic policies and deteriorating international conditions. China will remain innovative, but the extent of its success is not foretold. The West still has some leverage. The PRC may not be the copycat it has been accused of being, but its technological advancement continues to rely on the outside world, including Europe.[17]

11 Jürgen Matthes, "Gegenseitige Abhängigkeiten im Handel zwischen China, der EU und Deutschland. Eine empirische Faktensammlung" [Mutual trade dependencies between China, the EU and Germany: A collection of empirical facts], IW-Report 35/2022, Köln, Institut der Deutschen Wirtschaft, 2022, accessed 14 April 2024, at https://www.iwkoeln.de/fileadmin/user_upload/Studien/Report/PDF/2022/IW-Report-2022-Gegenseitige-Abhaengigkeiten.pdf

12 Graham Allison et al., *The Great Tech Rivalry: China vs the US* , Cambridge, MA, Belfer Center for Science and International Relations, 2021, accessed 22 October 2023, at https://www.belfercenter.org/sites/default/files/GreatTechRivalry_ChinavsUS_211207.pdf

13 Jamie Gaida et al., *ASPI's Critical Technology Tracker: The Global Race for Future Power*, Canberra, ASPI, 2023, accessed 22 October 2023, at https://ad-aspi.s3.ap-southeast-2.amazonaws.com/2023-03/ASPIs%20Critical%20Technology%20Tracker_0.pdf?VersionId=ndm5v4DRMfpLvu.x69Bi_VUdMVLp07jw.

14 Julia Voo et al., *National Cyber Power Index 2022*, Cambridge, MA, Harvard Kennedy School, 2022, accessed 23 October 2023, at https://www.belfercenter.org/publication/national-cyber-power-index-2022

15 Soumitra Dutta et al., *Global Innovation Index 2022: What is the Future of Innovation-driven Growth?* Geneva, World Intellectual Property Organisation, 2022, accessed 23 October 2023, at https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-en-main-report-global-innovation-index-2022-15th-edition.pdf

16 Regina M. Abrami et al., "Why China Can't Innovate", *Harvard Business Review*, accessed 18 September 2021, at https://hbr.org/2014/03/why-china-cant-innovate

17 Tim Rühlig, "The Roots of China's Innovativeness", op. cit.

This general observation, however, does not provide enough insight into the ways in which China relies on Europe and how the continent can maintain its technological indispensability to the PRC. Instead, Europe needs to understand China's technological ambitions, the weaknesses and obstacles the country faces on its way to achieving them and whether the PRC depends on Europe in this regard. In fact, Europe does not possess enough knowledge of its strengths and Chinese dependencies on the EU and the UK. It is this policy-relevant knowledge gap that this report seeks to tackle. We explore how Europe can remain technologically indispensable – or at least highly relevant – to China by examining 12 concrete technology case studies.

Our starting point is an analysis of Chinese-language sources identifying technological weaknesses and dependencies in specific cases. A previous study carried out by the Center for Security and Emerging Technology (CSET) at Georgetown University analysed a series of Chinese-language articles discussing technology chokepoints.[18] This report departs from CSET's previous results, investigating case studies by analysing both academic and policy documents in the Chinese language. The aim is to identify China's relevant technology ambitions and the obstacles that Chinese companies, researchers and policymakers must overcome.

This information on Chinese weaknesses is then matched with European technology strengths. For this, a triangulation of several data points helps to verify Chinese perceptions of its own technological weaknesses and identify whether Europe can match these weaknesses with its own strengths. Depending on the concrete case studies, these data points comprise the global research landscape measured by journal articles and conference papers, patent data, equity research data, public procurement data and/or technical assessments by the technical experts of DPC.

For this purpose, the report adopts a case study approach. Rather than aiming to grasp a full but vague picture based on import data, we explore 12 specific technology niches in detail that are of strategic relevance. Table 1 summarises the strategic relevance of the respective cases in each technological area.

All the case studies explore the potential for future European technology strengths with a time horizon of 10–15 years in mind. Accordingly, the cases examined need to be technology neutral enough to avoid technological determinism and the protection of European incumbents.

TABLE 1: Summary of chapter cases

SEMICONDUCTORS: LITHOGRAPHY EQUIPMENT
Jan-Peter Kleinhans and John Lee
Lithography is the most complex of the three basic steps in wafer fabrication. It is a highly concentrated market with an EU monopoly at the cutting-edge and an EU/Japanese duopoly in older technologies. Lithography is dependent on a lot of "auxiliary" equipment that needs to be closely integrated with the lithography machine.
WIRELESS INFRASTRUCTURE AND OPERATION: TOTAL ENERGY CONSUMPTION AND GREEN RADIO NETWORKS
Liesbet van der Perre, Tim Rühlig and Julian Heiss
Total energy consumption is one of three crucial factors (alongside performance and price) determining the competitiveness and sustainability of wireless infrastructure and transmission strategies. The primary focus is on RAN's total energy consumption. RAN is one of the two major mobile network infrastructure components (alongside the Core Network). It has been identified as a major bottleneck in energy consumption in high-capacity wireless networks.

18 Ben Murphy, *Chokepoints: China's Self-identified Strategic Technology Import Dependencies*, Washington DC, Center for Security and Emerging Technology, 2022, accessed 28 October 2023, at https://cset.georgetown.edu/publication/chokepoints/

QUANTUM: QUANTUM SENSING

Simon Armstrong, Abhishek Purohit, Michael Settelen and Araceli Venegas-Gomez

Quantum technologies are quantum computing and simulation, quantum communication, and quantum sensing and imaging. The case study focuses on the latter. Applications and use cases in quantum sensing impact various sectors, such as healthcare, material sensing, environmental monitoring and defence. If more focus is not put on these applications, this could weaken China. The EU has demonstrable strengths in quantum sensing over China, backed by its rich history in quantum research, structured and strategic investments in diverse quantum sensing technologies, and a well-established ecosystem that synergises academic and industrial components effectively.

BLOCKCHAIN: SMART CONTRACTS

Cyrille Artho and Rogier Creemers

Smart contracts are small pieces of software that automatically handle assets on a blockchain. They have the potential to significantly enhance the security of transactions. This is one of the major applications of blockchain discussed in both Europe and China. Once deployed, a smart contract cannot be changed; ensuring beforehand that the software has no major flaws is therefore of key importance. Research, development and innovation of smart contracts are seeing rapid growth, but wider adoption will require better development tools and agreements on common interfaces and platforms.

CRITICAL RAW MATERIALS: CHINA'S "STRATEGIC" METALS

Raphaël Danino-Perraud, John Seaman and Florian Vidal

A broad range of so-called technology metals are critical components of emerging technologies that will drive the digital and energy transitions. China remains dependent on foreign production of many metals it considers "strategic" for technological competitiveness. Such dependencies create vulnerabilities for Beijing, and there are particular concerns around supply disruption, even though China has made efforts to mitigate risks through investment and supply chain integration.

ARTIFICIAL INTELLIGENCE: MEDICAL DEVICES

Carlo Fischione, Sanne van der Lugt and Frans-Paul van der Putten

The Chinese government sees medical equipment as a sector in which it wants to be self-sufficient. Two European companies (Philips, Siemens) are among the world leaders for medical devices and deeply integrated into the Chinese medical and tech sectors.

SEMICONDUCTORS: AUTOMOTIVE CHIPS

Jan-Peter Kleinhans and John Lee

Automotive chips are sensors, power semiconductors, microcontrollers and autonomous driving chips. European chip suppliers are leaders in the first three categories. An electric vehicle (EV) has two or three times more chips than an internal combustion engine car. Chinese EV makers control more than 80% of China's EV market, which is the largest globally.

SPACE: MOON EXPLORATION

Marco Aliberti and Angela Stanzel

The provision of communication and navigation services is indispensable to sustaining a long-term robotic and/or human presence on the Moon. Communications and navigation represent just one critical technical area to be mastered for lunar exploration, but also the one with most application potential for commercial return on investments.

ARTIFICIAL INTELLIGENCE: FACIAL RECOGNITION

Gregory Walton and Valentin Weber

Facial recognition plays a small but important part in the Chinese economy's use of AI for industrial, consumer and citizen identification purposes. The Chinese facial recognition market is expected to reach €1.42bn by 2030. Facial recognition is essential to the modern surveillance state and a sizeable security industrial complex has emerged that exports the technology. Facial recognition is key to Beijing's communist elite remaining in power by allowing efficient monitoring of the population.

ARTIFICIAL INTELLIGENCE / DATA GOVERNANCE: GENOMIC DATA

Una Berzina-Cerenkova, Elena Ferrari, Karina Palkova and Julia Voo

European Genomic data is indispensable to China's bio-tech and med-tech research and exports. Responsible data governance of genomic data is a strategic asset for the EU, especially in the case of cross-border collaborations. The Chinese government regards bio-tech as a national priority to be sustained through massive investments in technologies for genomic data analysis.

TECHNICAL STANDARDS: STANDARDS IN 5G ENERGY CONSUMPTION, AUTOMOTIVE CHIPS AND FACIAL RECOGNITION

Martin Catarata and Tim Rühlig

The analysis covers a subset of three emerging technology standards foundational to defining crucial developments in the respective technologies: (a) 5G energy consumption for the competitiveness and sustainability of future wireless infrastructure; (b) cutting-edge automotive chipsets for the development of secure and reliable autonomous driving; and (c) AI facial recognition for privacy protection in an "inherently learning" technology.

DIGITAL AND GREEN TRANSITIONS: OPPORTUNITIES AND CHALLENGES FOR EUROPE AND CHINA

Davide Bonaglia, Rasmus Lema, Mercedes Menéndez de Medina and Roberta Rabelotti

The number of digital green patents has risen sharply since 2010; 70% of digital green patents are in technologies whose purpose is to minimise the use of energy during the operation of the ICT equipment involved. The EU has technology advantage in technologies related with energy generation, transmission, and distribution and those related with wastewater treatment or waste management. China has not yet developed any are of technology advantage in digital green technologies.

FROM TECHNOLOGICAL STRENGTH TO POLITICAL LEVERAGE

China has profited greatly from technological upgrading. The PRC has been undergoing a process of technological catch-up for several decades. Legitimate and illegitimate technology transfer from Europe to China have contributed significantly to the PRC's rise to become the world's second-largest economy.[19] China's technological advance remains central to the development of the PRC, which is facing several structural challenges. As its demographic dividend and urbanisation potential draw to an end, China needs to undergo structural reform. China can no longer compete on cheap skilled labour, but needs to move up the global value chain and sustain as much productivity growth as possible. For this, technological innovation and advance will be central. In 2016, an official of the National Development and Reform Commission (NDRC) explained in an anonymous interview that "to ensure social stability, we need to achieve significant productivity gains from digital technologies. Only if we stay on top of digital technologies

19 Jyh-an Lee, "Forced Technology Transfer in the Case of China", in *Journal of Science Technology Law*, vol. 26, no. 2, pp. 324–352, September 2020.

can we remain competitive and prevent the middle-income trap.[20] [...] We need to make sure that we do not grow old before we get rich".[21]

From this context, we can understand that China's leadership puts great emphasis on technological development. In his speech to the 20th CCP Party Congress, paramount leader Xi Jinping identified technological advance and self-reliance as key to the country's economic prosperity and national strength.[22] Equally, China's most recent Five-Year Plan prioritises innovation and characterises domestic self-reliance as the main objective not only for domestic development, but also as a basis for the PRC's global power.[23] It is therefore no wonder that Xi Jinping has continuously identified a strengthening of basic research as a decisive feature of the government's work.[24]

While China's persistent dependence on foreign technology, including from Europe, provides potential leverage for the EU and the UK, not every European technological strength has equal political leverage. To properly assess the political leverage of a technological strength, policymakers need to take various aspects into account.

Area of indispensability: Europe's strength could be based on superior research and innovation, intellectual property and patents, or production and commercial goods. Such a distinction is crucial if policymakers are to understand how to provide the conditions for maintaining their respective European strongholds.

Market entry barriers: What would it take for China to achieve import substitution and reduce its dependence on European technology providers? Are the barriers to successful market entry by Chinese technology providers mainly rooted in: (a) technological breakthroughs; (b) economies of scale; or (c) compliance with standards and certification? Or are there no substantial barriers to entry at all, and could the dominant market position of a European technology provider rapidly dwindle?

Technological substitutability: One technology can often be substituted with another even if that means settling for decreased performance, higher costs or lack of certain capabilities. One example would be wafer fabrication at the 7nm level, which can be achieved either with extreme ultra-violet (EUV) equipment or through the use of older deep ultra-violet (DUV) equipment. The latter, however, increases production time, cost and defects rates.

Foreign availability: Reducing dependence on a European technology provider by strengthening the domestic supplier ecosystem can take a long time. Sometimes a short- to medium-term solution might be to diversify through foreign, non-European suppliers. Thus, foreign availability dilutes the strength of a chokepoint.

Effective utilisation: Controlling a European technological strength through, for example, export controls might be ineffective or unenforceable. For instance, restricting exports is substantially harder for software and other intangible technologies than for tangible goods, such as industrial machinery. A different example would be Europe's strength in medical equipment: given that the protection of lives depends on the technology, it is questionable whether Europe should use it as a chokepoint for geopolitical purposes.

EUROPEAN AMBITIONS

Technological strengths and the degree of leverage they carry say little about the political ambitions that Europe is seeking to achieve by using them. The feasibility of different levels of ambition varies according to the concrete technological ecosystem. However, the level of ambition is also a matter of political will. Europe needs to calibrate its levels of ambition and be realistic about what it can and what it wants to gain politically from a given (potential) technological strength. At least four levels of ambition can be distinguished:

20 The middle-income trap refers to the phenomenon that a middle-income country's economic development stalls below what is needed to achieve a high per capita income. This is the effect of rising labour costs and the resultant decline in competitiveness before the population has progressed to high income levels.

21 Anonymous author interview with an official of the NDRC, Beijing, July 2016.

22 Ministry of Foreign Affairs of the People's Republic of China, "Full Text of the Report to the 20th National Congress of the Communist Party of China", Beijing, Chinese Government, 2022, accessed 29 October 2023, at https://www.fmprc.gov.cn/eng/zxxx_662805/202210/t20221025_10791908.html

23 Government of the PRC, "中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要" [Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035], State Council, accessed 29 October 2023, at https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm

24 See e.g. Xi Jinping, "加强基础研究 实现高水平科技自立自强" [Strengthening basic research to realise high-level scientific and technological self-reliance and self-improvement], Qiushi, accessed 29 October 2023, at http://www.qstheory.cn/dukan/qs/2023-07/31/c_1129776375.htm?utm

- **Threat prevention** is the lowest level of ambition. It has only one goal in mind: to prevent the transfer of technology to China that could be used to threaten Europe. Threat prevention aims to increase European security by preventing dual-use technology leakage to China, defined along the lines of the Wassenaar Arrangement and the EU dual-use export control regulation (2021/821), as well as the UK's Export Control Act 2002 (ECA 2002) and the associated Export Control Order SI 2008/3231.

- The **ability to deny** is more ambitious as it is about maintaining or creating co-dependencies that constitute a high degree of economic cost for China if Europe were to leverage its strength by means of technological disentanglement. This level of ambition follows a defensive logic as Europe simply wants to prevent China from acting against core European interests. In contrast to the first level, the ability to deny considers not just dual-use goods, but economic dependencies more broadly. Resting on the assumption that China is unlikely to accept irrationally high economic costs, it seeks to use the cost of interdependencies to deter the PRC from acting against core European interests.

- The **ability to act** capitalises on the same rationale of economic cost through interdependence but is more proactive in that it strives to maintain an edge over China. The ability to act is not purely defensive. Instead, it represents a degree of Chinese technological reliance on European strength that allows the EU to shape technological development and related policy directly and indirectly through third markets. China often strives for the ability to act, for example, through controls on exporting graphite from China to Sweden.[25] Graphite exports are controlled by the PRC not for security purposes or to reactively prevent Sweden from going against Chinese core interests. Instead, the likely purpose is to hamper one of Europe's most important EV battery production sights, thereby maintaining European reliance on Chinese EV batteries.

- **Curtailment** is about preventing the respective other from developing certain economic and technological capabilities far beyond the security realm. The goal is to limit and freeze Chinese technological and economic development more broadly. US semiconductor export controls are a recent example of curtailment as they cut China off from advanced generative AI development.

In each technological ecosystem, European policymakers need to identify the level of ambition given the feasibility of the actions required to achieve a stated ambition. This report therefore structures its policy recommendations along the above four levels of ambition, outlining which policies the EU and the UK need to put in place in each case study. In this context, European policies need to start from a proper understanding of Chinese ambitions, technological ecosystems and existing strategic niches with the potential for leverage, to all of which this report strives to contribute.

FINDINGS ACROSS CASE STUDIES

The character and degree of potential European technological indispensability, the mechanisms for leveraging it and the policies that Europe should put in place vary across the technological areas analysed in this study. However, seven patterns visible across all cases are summarised below.

FINDING 1: Europe's greatest source of strength is research and innovation, but IP and production contribute too

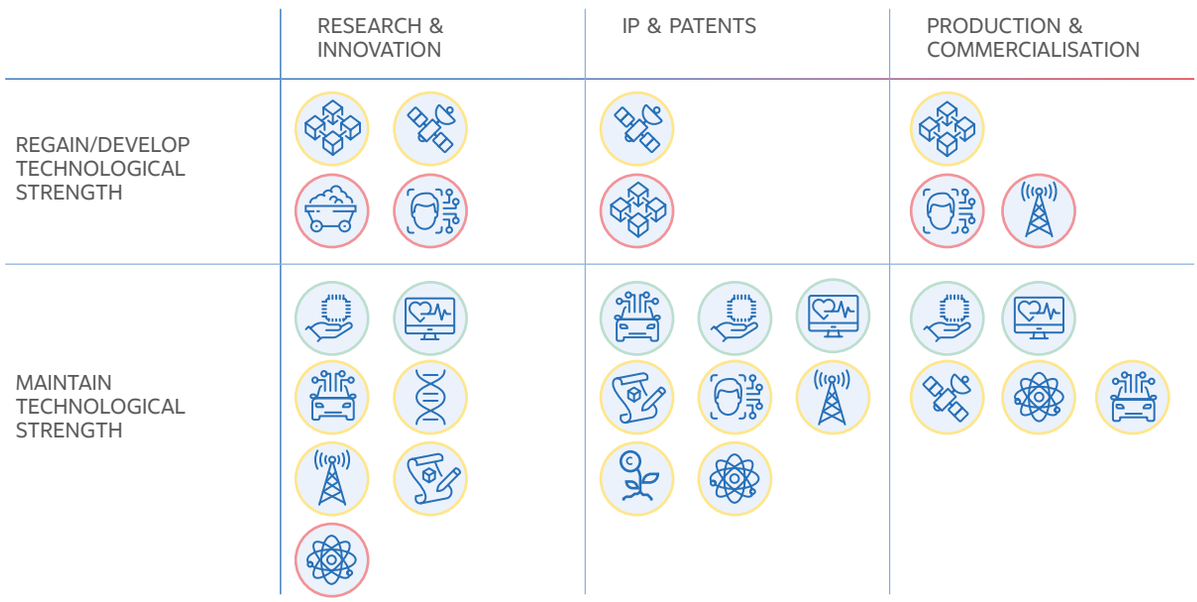
Across the case studies analysed, European strength can result from excellent research and innovation, IP and patents or the production and commercialisation of the respective technologies. In many cases, Europe's potential for leverage results from a combination of these sources. In some cases, Europe is well placed to develop or regain technological strength in one or several of these three dimensions. In other cases, the EU is already well placed and should strive to maintain and consolidate the technological edge it currently holds.

It is widely known that Europe's technological capabilities are stronger in research and innovation than in IP and production.[26] However, the cases illustrate that this general finding on European research and innovation strength does not preclude that technological excellence in critical niches can equally result from IP and commercial products. European strategic indispensability, if achieved, will emerge from a combination of all three pillars.

25 Shunsuke Tabeta and Iori Kawate, "China's Graphite Export Curbs Take Effect With Uncertainty For EVs" *Nikkei Asia*, accessed 20 December 2023, at https://asia.nikkei.com/Spotlight/Supply-Chain/China-s-graphite-export-curbs-take-effect-with-uncertainty-for-EVs

26 See e.g. the results of the first DPC report, Tim Rühlig (ed.), China's Digital Power op. cit.

FIGURE 1: Existing and potential sources of European technological strength across the analysed case studies



KEY

Green icons = highest likelihood that Europe will achieve its goals if its puts in place the right policies
Yellow icons = medium level of likelihood that Europe will achieve its goals if its puts in place the right policies
Red icons = even were Europe to put in place the right policies, it would face difficulties achieving its goals

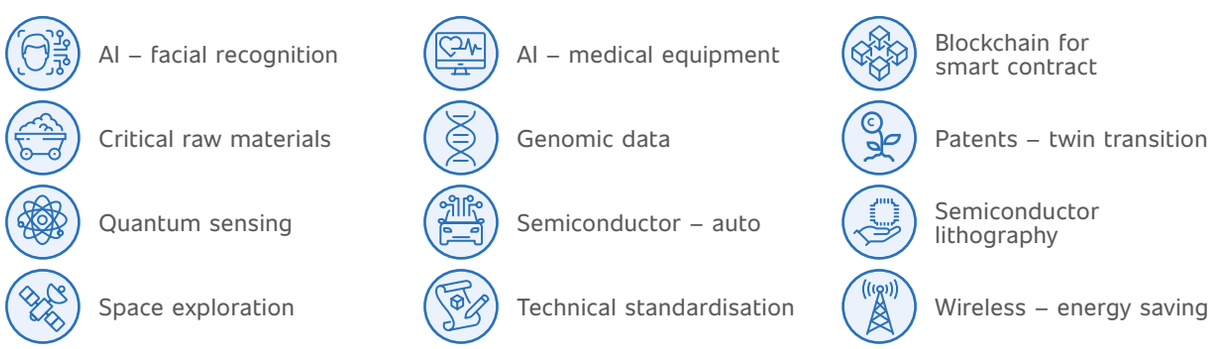
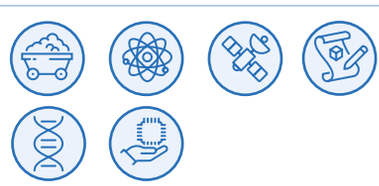


Figure 1 summarises the existing and potential sources of European technological strength across the analysed case studies. The colour coding of the icons indicates the likelihood of Europe developing or maintaining a technological edge over China within a timeframe of 10 years. Icons are not displayed in a given column if there is no realistic chance of achieving technological strength in the respective pillar.

FINDING 2: Technological superiority, and commercial, political and regulatory aspects are all decisive factors in European technological indispensability

European technological strength is the result of more than just technological excellence. Depending on the technology ecosystem, economic factors such as a strong market position, better commercialisation conditions, the integration of a technology into products or access to the European Single Market can play a decisive role. Political and regulatory conditions such as legal certainty, Europe's normative power or the priority it gives to the sustainable development of technologies are also factors. In some cases, a combination of

FIGURE 2: Sources of potential European strength across the analysed case studies

	CATEGORY	CASES
TECHNOLOGICAL EXCELLENCE	TECHNOLOGICAL	
STRONG MARKET POSITION/ BETTER COMMERCIALISATION/ BETTER PRODUCT INTEGRATION	ECONOMIC	
MARKET ACCESS	ECONOMIC	
POLITICAL/ REGULATORY FACTORS (SUCH AS LEGAL/ REGULATORY CERTAINTY, NORMATIVE INFLUENCE, POWER STATUS)	POLITICAL/ LEGAL	
SUSTAINABILITY	POLITICAL/ REGULATORY (but also technological and economic)	
RESEARCH PARTNERSHIPS	TECHNOLOGICAL/ ECONOMIC/ POLITICAL	

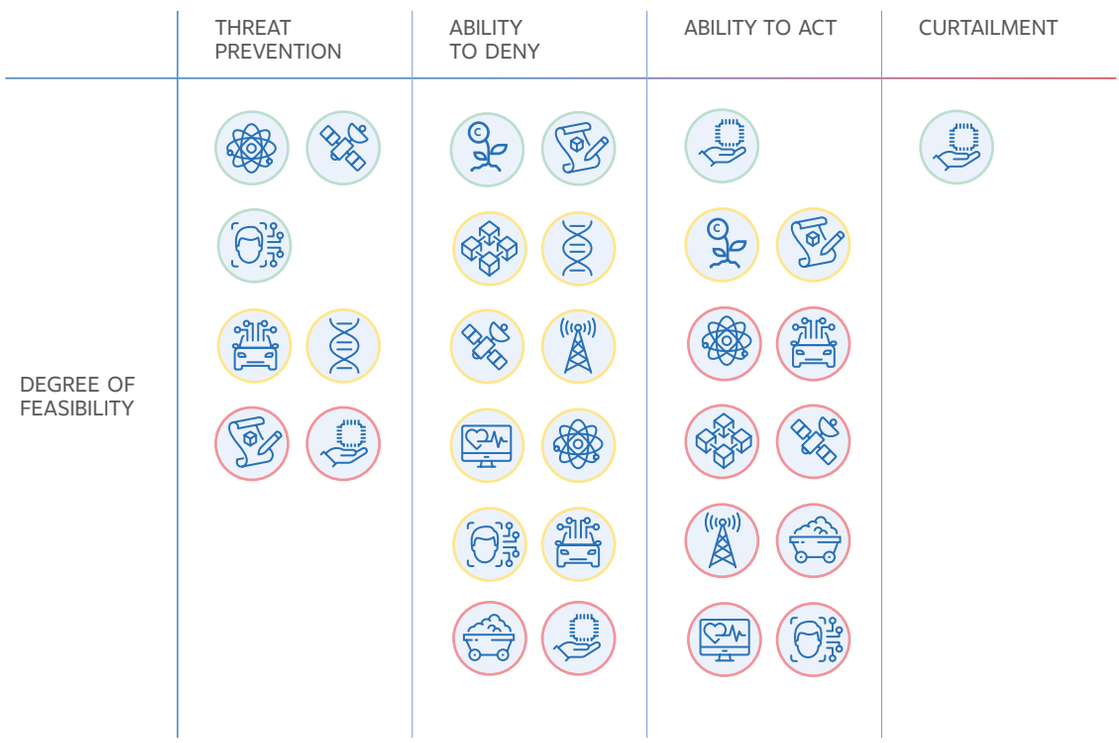
technological, economic and political factors has resulted in technology partnerships that give Europe an edge over China. Figure 2 summarises the sources of potential European strength across the analysed case studies.

FINDING 3: Europe should calibrate its levels of ambition technology by technology

When considering technological indispensability and the resulting chokepoints, observers automatically think of China's reliance on European advanced semiconductor manufacturing equipment. This hard chokepoint, often associated with the Dutch vendor ASML, is a unique case of a complex technological ecosystem that relies on a broad range of mostly European suppliers that would be almost impossible to replicate. No other hard chokepoint of the same quality exists in the analysed digital technologies.

This means that of the analysed cases, curtailment is only feasible in lithography. Other levels of ambition, however, are achievable depending on the technological ecosystem. Figure 3 summarises the likelihood that the right policy choices would allow Europe to achieve its respective levels of ambition in the analysed cases. The colour coding indicates the likelihood that Europe could achieve the respective level of ambition in a timeframe of 10 years if the right policies were put in place. Where an icon is not displayed in a respective box, this level of ambition is not feasible.

FIGURE 3: The likelihood that the right policy choices would allow Europe to achieve its respective levels of ambition in a timeframe of 10 years



When considering different levels of ambition, European policymakers face trade-offs inherent in all four levels. Some of these are technology-specific, others more general.

- **Threat prevention:** A targeted focus on dual-use items makes considerations less complex and allows for a maximum of economic and technological exchange with the PRC compared to the other levels of ambition. At the same time, Europe constrains itself to preventing technology leakage without any additional leverage beyond this narrow aim.

- **Ability to deny:** A focus on mutual dependency accepts a certain level of vulnerability inherent in interdependency while maintaining a significant degree of interaction and its resultant revenue for EU actors. This strategy assumes that China, unlike Russia, is a cost-sensitive and rational actor seeking to avoid acting against core European interests, as this would place significant constraints on China's domestic economy and technological development. If China's economic crisis deepens, however, the PRC could act irrationally. Alternatively, the EU could miscalculate the distribution of dependency and enter a stage of asymmetric dependency.

- **Ability to act:** A high degree of leverage would result from Chinese dependence on European technological input. Europe could not only shape China's calculations in a major crisis, but also influence technological and related policy developments in the PRC. At the same time, Europe would increase its economic and security risk as a high level of cooperation would strengthen Chinese capabilities.

- **Curtailment:** If successful, a relative gain in power compared to China would come at an economic cost, slowed innovation and an undermining not least of global ambitions on climate change mitigation; it also runs the highest risk of Chinese retaliation.

FINDING 4: Not every European technological strength has the same degree of political leverage

Technological strength is a necessary but not sufficient precondition for European leverage over China. Whether Europe is able to leverage a given technological strength depends on a number of factors, not least ethical considerations, the degree of difficulty substituting the respective technology and the spillover effect into other factors. For example, withholding medical technology is likely to be less acceptable and therefore politically less

FIGURE 4: Degree of leverage

feasible in European democracies. Figure 4 summarises the degree of leverage across technology ecosystems.

Figure 5 summarises the analysed case studies along two dimensions that influence the degree to which technological strength provides leverage: substitutability and expected spillover damage if ties with China were to be cut. The figure does not consider the possibility of asymmetric retaliation.[27] Note that spillover can differ; for example, the damage in auto chips would mostly be a significant decrease in European suppliers' revenues and related effects while spillover in critical raw materials would result from China's leverage and retaliatory capabilities. Figure 5 shows a correlation between the degree of difficulty in replicating or circumventing European technological strength and the expected degree of spillover.

FINDING 5: Integrate strategic and commercial considerations for a durable technology policy

To a large extent, Europe's technological strength is the strength of commercial actors and that of publicly funded research institutions such as universities. It is in Europe's strategic interest to maintain and further develop these strengths in order to retain leverage. A durable strategy requires a conducive environment in which commercial actors can flourish. However, commercial actors do not necessarily consider strategic priorities to a sufficient degree.

Strategic objectives can also be turned into commercial opportunities. For example, even when an uneven playing field of commercial competition between the EU and China puts European market actors at a disadvantage where competition is solely or mostly over price, the creation of markets for trustworthy technologies can create commercial opportunities.

Europe should develop its technology policy from the starting point that it is unavoidable that companies and consumers will have to pay a premium to cover growing geopolitical risks in the medium term. EU and UK policy need to start from the objective of reducing this inescapable price. Therefore, in the triangle of promote, protect and partner, promote and partner tools that take account of the technology markets will require at least as much attention as protect instruments. Furthermore, such a policy should be framed as an attempt to reduce broader societal insecurity over European economic and technological development, and explicitly strive to increase societal cohesion and trust.

FINDING 6: Balance strategic entanglement and autonomy as two elements for achieving European security.

Having identified that dependence on a foreign supplier of critical technology poses a security risk to Europe, the following step is to identify the degree to which this risk can be addressed through either entanglement (indispensability) or autonomy.

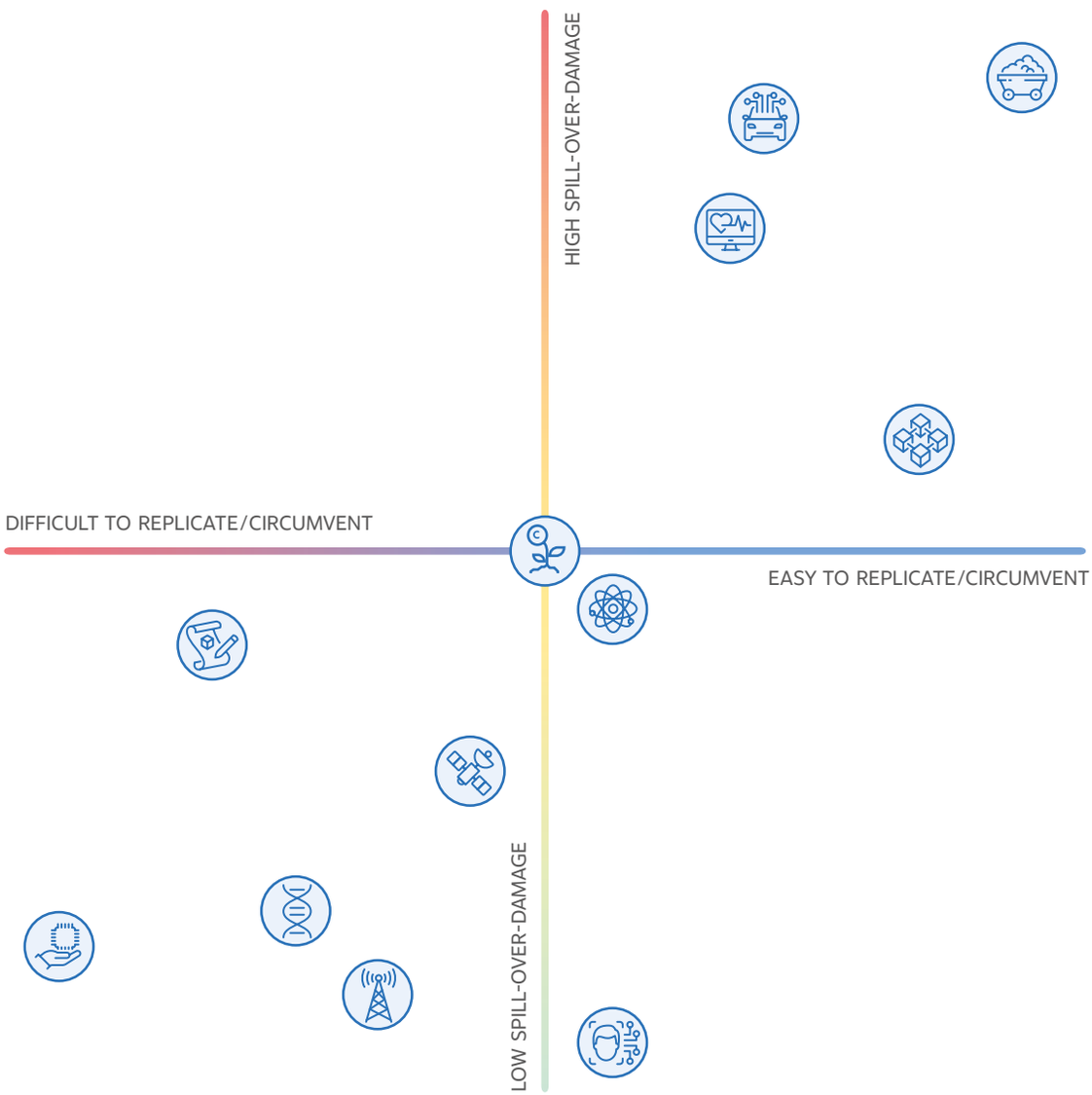
- **Entanglement** (Indispensability): If European and Chinese technology suppliers are entangled in a critical technology ecosystem, Europe's long-term policy objective should be to ensure or achieve indispensability within entanglement. The goal is for European technology to play an indispensable role in the Chinese technology ecosystem. Strategic entanglement creates security through indispensability. Targeted reverse dependencies keep the cost of conflict very high for China.

- **Autonomy:** Autonomy reduces Europe's dependence and vulnerability and thereby increases European security. However, a technologically independent or self-reliant China in turn poses security challenges for Europe.

This distinction does not ignore the fact that there will be regular economic interaction between the EU and China that does not fall into the category of strategic entanglement. However, the objective of this study is

27 For example, a tightening of European semiconductor export controls could result in tighter and broader Chinese export restrictions on critical raw materials. Figure 5 considers technology-inherent spillover risks, i.e., the risk of retaliation in the very same technology. It can be hypothesised that the likelihood of asymmetric retaliation largely depends on the damage to China caused by the respective European action. Testing this hypothesis, however, is beyond the scope of this volume.

FIGURE 5: The degree to which technological strength provides leverage: substitutability and expected spillover



to identify under which circumstances, how much and what kind of interaction with China can increase European security, and when autonomy should be the strategy of choice. Autonomy and strategic entanglement are two poles on a continuum and must be properly balanced. This balance varies across technology ecosystems but also depends on the level of European ambition, as outlined above.

FINDING 7: Policy recommendations for Europe are technology-specific and vary according to levels of ambition, from research promotion to knowledge security and commercialisation

European policy on developing or maintaining technological indispensability in critical technological niches requires case-specific policies. No one-size-fits-all approach can provide conducive conditions for, let alone a guarantee of retaining technological indispensability.

The comparison of analysed cases does illustrate, however, that policies vary depending on level of ambition (as outlined in finding 3) and depending on the role of autonomy and strategic entanglement as sources of security (as outlined in finding 6). Furthermore, in all cases, a combination of policies that promote research and innovation, protect IP and patents, and provide conducive conditions for production and commercialisation are essential to increasing European security by means of strategic indispensability.

A comparison of the policy instruments proposed for the respective four levels of ambition identifies a number of patterns. To achieve *threat prevention*, an analysis and tracking of the risks of dual-use applications is often mentioned along with export controls, inbound and outbound investment screening, as well as strengthened oversight and enforcement of existing rules. These measures focus on knowledge security. Within the EU's triangle of promote, protect and partner tools, there is a heavy emphasis on protect instruments.

Achieving the *ability to deny* in the 12 technology ecosystems discussed in this report tends to require a different set of tools. Strengthening European public and private sector research by various means; deepening the Single Market/UK market to provide conditions that incentivise faster adoption and rollout of critical technologies, such as through public procurement and tax incentives; cooperation with third countries while also allowing European engagement in the Chinese market and cooperation with Chinese companies; as well as inbound investment screening and enforcement of intellectual property rights along with strong engagement to set regulatory norms and technical standards in Europe and internationally are all frequently recommended. These tools mostly focus on research promotion and support for commercialisation. Thus, promote and partner instruments are vital along with minor protect tools.

At first glance, the policy instruments to achieve the *ability to act* appear similar to those for the ability to deny. Strengthening of research and commercialisation conditions in Europe, public investment, digital free trade agreements with third countries, and strong commitment to norms and standards in the EU and internationally all read as somewhat the same even if with a bit more ambition. However, the tools far exceed those of the ability to deny. Coordinating research collaboration and coordinating industrial policies with third countries are complex and demanding. Public investment is often mentioned in the context of high-risk/high-gain constellations that call on public actors to take on the risks of default. Coupled with a call to attract talent and the aspiration to even influence domestic standard setting in China, this illustrates that this level of ambition seeks to establish Europe as a technology leader. In contrast to the ability to deny, this will require strong and proactive collaboration with third countries, but also targeted defensive measures such as anti-dumping and anti-subsidy instruments and IP rights enforcement in cooperation with third countries, targeted outbound investment screening and inbound investment screening. Comprehensive policy instruments would involve research promotion, knowledge security and commercialisation support tools. All three angles of promote, protect and partner would play an important role with a strong emphasis on partner tools.

Curtailment, finally, is about export controls, outbound investment screening, the enforcement of intellectual property rights but also strategies to buffer the economic losses that European companies and economies would face. "Protect" tools for ensuring knowledge security will be key.

This is not to say that all of these instruments are crucial in all cases or that instruments that are not mentioned in this list cannot be important in individual technology ecosystems. Table 2 summarises the patterns but European policymakers must not neglect the specific characteristics of different technology ecosystems.

Many of the policy instruments currently being widely discussed in the European Union and the United Kingdom appear in at least some of the chapters of this report: (a) continuous risk assessments; (b) increased promotion of technologies, including dual-use technologies; (c) high-risk/high-gain investments by public actors as a means of deepening the Single Market; (d) strong engagement in international norm- and standard-setting; (e) comprehensive coordination with third countries, including on research promotion but also industrial policy; (f) new and deepened existing free trade agreements; (g) tightened inbound investment screening and export controls; and (h) limitations on research collaboration with Chinese actors. Most remarkably, outbound investment screening to prevent the export of innovation capabilities from Europe to China is discussed not only in a narrow security context, but also as a factor in preserving European competitiveness.

Finally, European policymakers need to balance protective measures with openness to China. A further challenge will be for policies to remain technology agnostic and avoid the trap of simply protecting incumbents. European policy responses must adequately address geopolitical challenges while remaining economically viable in the environment of European free market economies, and take account of specific emerging or foundational technologies.

TABLE 2: Patterns of recommended policy instruments sorted by level of ambition

	THREAT PREVENTION	ABILITY TO DENY	ABILITY TO ACT	CURTAILMENT
Frequently mentioned policy instruments across the twelve analysed technology ecosystems	• Identify dual-use goods, establish a risk tracker • Export controls • Inbound investment screening • Outbound investment screening • Strengthen oversight and enforcement	• Strengthen European research (public funding, tax incentives, promotion of academic-commercial collaboration) • Deepening of Single Market/UK Market for quicker technology rollout, including tax incentives and public procurement • Increase cooperation with third countries, including Free Trade Agreements • Allow European engagement and partnership by European companies in China • Regulatory and standards engagement in Europe and internationally • Inbound investment screening • Consequent enforcement of intellectual property rights	• Strengthened European research coupled with research collaboration with third countries (public funding, tax incentives, promotion of academic-commercial collaboration) • Coordinated industrial policy and instruments to incentivise technology rollout in Europe and in like-minded third countries • Digital Free Trade Agreements • Deepening of Single Market/UK Market for quicker technology rollout, including tax incentives and public procurement • Public high-risk/high-gain investments • Active policies to attract talent • Strong commitment to setting norms and standards in the EU, internationally and in China • Strong enforcement measures of international principles including anti-dumping, anti-subsidy instruments and IP rights enforcement in cooperation with third countries • Targeted outbound investment screening • Inbound investment screening	• Export controls • Outbound investment screening • IP rights enforcement • Strategies to buffer economic losses of European companies
Policy focuses on the "Protect, Promote, Partner" triangle	• Protect	• Promote • Partner	• Protect • Promote • Partner	• Protect
Source of European technology strength in focus	• Knowledge security	• Research promotion • Commercialisation	• Research promotion • Knowledge security • Commercialisation	• Knowledge security

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