China and the Industrial Internet of Things

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Contents

Introduction

Expansion of the internet of things (IoT), through which a growing range of objects are connected and controlled over digital networks, is among the defining technological trends of the 21st century. For over a decade, China has promoted the IoT's development as a strategic priority.[1] Within the concept of the IoT, the Chinese state has given special emphasis to the 'Industrial Internet' (工业互联网; in English global usage, generally described as the 'Industrial Internet of things', or 'IIoT'): namely, the use of digital networking to automate and optimise industrial processes, and particularly manufacturing. This reflects China's role as a global manufacturing hub and its goal of moving up the technological ladder, thereby capturing greater value from globalised supply chains and dominant positions in the emerging industries of the future.

The development of China's IIoT is projected to be the major source of IoT growth in the Asia-Pacific region over the coming decade.[2] The IoT is also an expanding sector in Europe, with the market for IoT products and services expected to maintain double digit growth through 2026.[3] As European economies look to the wider Asia-Pacific region for economic partnerships, partly to diversify away from China, they face the prospect of being enmeshed in regional IoT ecosystems within which the presence of Chinese technology is steadily rising.[4] European firms – specifically, German ones – are also still significant actors in developing China's IIoT, despite the growing pressures imposed by Chinese and US regulatory measures.

Because the IoT involves massive information flows and mass networking of controllable devices, it imports major challenges for data and physical security. As the Chinese economy's global integration through digital networks rises, this amplifies the risks stemming from

[1] Lee, J. (8 December, 2021). 'The internet of things: China's rise and Australia's choices.' Lowy Institute. Retrieved from: https://www.lowyinstitute.org/publications/internet-things-chinas-rise-and-australias-choices

[2] Tomás, P. (16 June, 2022). 'IoT spending in Asia-Pacific to reach $436 billion in 2026: IDC'. *RCR Wireless*. Retrieved from: https://enterpriseiotinsights.com/20220616/internet-of-things/iot-spending-asia-pacific-reach-436-billion-2026-idc

[3] IDC. (10 June, 2022). 'European IoT Spending Continues Its Double-Digit Growth, Despite Global Uncertainty and Slow Demand, Says IDC'. Retrieved from: https://www.idc.com/getdoc.jsp?containerId=prEUR149276822

[4] Lee, J. (8 December, 2021). 'The internet of things: China's rise and Australia's choices.' Lowy Institute. Retrieved from: : https://www.lowyinstitute.org/publications/internet-things-chinas-rise-and-australias-choices

political tensions with Beijing. These challenges have acquired new urgency since late 2022, with clear moves by the US government towards a policy of technological 'containment' of China, and allied countries increasingly under pressure to follow Washington's lead.

This report first explains the policy context for the IIoT's development in China. It then reviews the state of China's IIoT sector and its relationship to current policy goals, in particular the 2021-2023 industrial development plan and the 14th Five Year Plan for Smart manufacturing. The report next examines the Chinese state's management of IoT security and the implications that this raises from a European viewpoint. Finally, the report offers recommendations for European policymakers to respond to these challenges.

1. Global growth of the IoT and the IIoT

Over the past two decades, the spread of computing power and connection to the internet has steadily transformed societies worldwide. Advances in digital networking technologies, processing and storage, and sensors and actuators have combined to fuel the IoT's rise and specific application in manufacturing.[5] By one recent estimate, the number of IoT devices worldwide will nearly triple over 2020-2030, from 9.7 billion to more than 29 billion.[6] In 2022, IoT spending was anticipated to reach $US1.2 trillion worldwide, dominated by manufacturing and transportation.[7]

Since the mid-2010s, the EU has promoted development of the IoT as an enabling prerequisite for the digital transformation of Europe's economy.[8] A particular focus has been the IoT's application to industry, enabling process automation and optimisation that will allow potentially revolutionary gains in efficiency and flexibility of production. Expressed in the concept of the 'Fourth Industrial Revolution' (4IR) - itself inspired by Germany's Industrie 4.0 strategy for next-generation manufacturing[9] - this is recognised as a crucial trend for European industry's global competitiveness.[10] Europe's cross-sectoral Alliance for IoT Innovation was established in 2015 to match creation of industry consortia for developing the IIoT in the US and Japan. This was soon followed by China with its own Alliance for the

[5] Schmid, R. (2018). 'Industrial IoT: How Connected Things are Changing Manufacturing'. *Wired.* Retrieved from: https://www.wired.com/wiredinsider/2018/07/industrial-iot-how-connected-things-are-changing-manufacturing/

[6] Vailshery, L. (22 November, 2022). 'Number of Internet of Things (IoT) connected devices worldwide from 2019 to 2021, with forecasts from 2022 to 20300'. Statista. Retrieved from: https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/

[7] Internet of Business. (2018). 'IoT spending to hit $1.2 trillion by 2022, claims IDC'. Retrieved from: https://internetofbusiness.com/iot-spending-to-hit-1-2-trillion-by-2022-claims-idc/

[8] European Commission. (2016). 'Digitising European Industry: Reaping the full benefits of a Digital Single Market'. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0180&from=EN

[9] Platform Industrie 4.0. '2030 Vision for Industrie 4.0: Shaping Digital Ecosystems Globally.' Retrieved from: https://www.plattform-i40.de/IP/Navigation/EN/Industrie40/Vision/vision.html.

[10] European Commission. (19 April 2016). 'Advancing the Internet of Things in Europe'. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0110&from=EN

Industrial Internet, under a new policy (IIoT Opinions, below) that framed China's IIoT development as competing with that of developed countries.[11]

The Asia-Pacific is both the world economy's fastest growing region and the region now spending most on the IoT.[12] This growth in regional IoT spending is dominated by industrial implementations and particularly manufacturing, and is being led by China, which in 2022 accounted for 60% of IoT spending in this region excluding Japan.[13] The industrial applications and telecoms infrastructure-led expansion of the IoT in China is not simply an organic development, but the result of sustained state policy.

[11] Alliance of Industrial Internet. 'About AII'. Retrieved from: http://en.aii-alliance.org/index.php?m=content&c=index&a=lists&catid=7

[12] International Monetary Fund. (27 October, 2022). 'Regional Economic Outlook for Asia and Pacific, October 2022'. Retrieved from: https://www.imf.org/en/publications/REO?sortby=Region&series=Asia+and+Pacific; Vailshery, L. (28 June 2022). 'Prognosis of worldwide spending on the Internet of Things (IoT) from 2018 to 2023'. Statista. Retrieved from: https://www.statista.com/statistics/668996/worldwide-expenditures-for-the-internet-of-things/

[13] Tomás, P. (16 June, 2022). 'IoT spending in Asia-Pacific to reach $436 billion in 2026: IDC'. *RCR Wireless*. Retrieved from: https://enterpriseiotinsights.com/20220616/internet-of-things/iot-spending-asia-pacific-reach-436-billion-2026-idc

2. The IIoT and China's strategic technology/industrial policy

'Informatisation', innovation and the real economy

'Informatisation', meaning ubiquitous application of digital information and communications technology (ICT), has been endorsed for over two decades at the highest levels of China's political system as a guiding concept for the nation's development.[14] In this context, state policy has tracked the global trend towards integrating 'the internet in everything,'[15] by encouraging the development by Chinese industry of IoT-enabling technologies and building out infrastructure such as 5G telecoms networks. National policy has promoted the IoT as a discrete priority since 2009, when it was identified as a strategic emerging technology.[16] Chinese authorities have fostered development of enabling technologies, such as networked sensing systems and 'Narrowband IoT' wireless telecoms, through designated industrial R&D clusters, demonstration zones and industrial partnerships.[17]

All this activity sits within China's larger policy framework of an 'innovation-led development strategy'. Pursuing emerging technologies is expected to eventually produce far-reaching revolutionary effects the fruits will be reaped by those nations whose firms are already leaders in the underlying systems.[18] This approach reflects the original concept of the 4IR, with its focus on 'megatrends' such as the IoT's expansion that are predicted to drive paradigm shifts in business and society.[19] Such a view encourages uptake of the IoT and other

[14] Lee, J. (June 2022). 'Cyberspace Governance in China: Evolution, Features and Future Trends'. *Institut français des relations internationales*. Retrived from: https://www.ifri.org/en/publications/notes-de-lifri/asie-visions/cyberspace-governance-china-evolution-features-and-future. pp9-10.

[15] DeNardis, L. (2020). *The Internet in Everything: Freedom and Security in a World with No Off Switch*. Yale University Press.

[16] Lee, J. (8 December, 2021). The internet of things: China's rise and Australia's choices. Lowy Institute. Retrieved from: : https://www.lowyinstitute.org/publications/internet-things-chinas-rise-and-australias-choices, p7.

[17] Ibid, pp7-8.

[18] Naughton, B. (2021). *The Rise of China's Industrial Policy, 1978-2020*. Universidad Nacional Autónoma de México.

[19] Schwab, K. (2017). *The Fourth Industrial Revolution*. Penguin UK.

emerging technologies for their future transformative potential and spillover benefits, notwithstanding that these have yet to materialise at the envisioned scale.

Digital transformation in China has a unique emphasis on the IIoT, given the state's choice to perpetuate a supply side-led economic growth model driven by investment and export manufacturing.[20] Industrial application of the IoT promises to address China's well-known problems of stalling productivity growth, demographic ageing and other development challenges. Under Xi Jinping's leadership, the state has focused on ensuring that further digitalisation of China's economy does not simply inflate the profits of internet services firms, but rather serves the 'real economy' and particularly manufacturing, identified as the foundation for China's long-term development.[21]

This priority was reiterated in a new 14th Five Year Plan for National Informatisation (FYPNI) issued in December 2021.[22] The FYPNI outlines ten 'priority tasks' for China's further informatisation, one of which is 'building a development system for the digital transformation of industry.' Within this general priority, special attention is given to digital transformation of the manufacturing sector, along the lines set out in China's extant dedicated IIoT development plans (discussed below). This section of the FYPNI emphasises the IIoT's integration with 5G, big data, blockchain, artificial intelligence and other 'new generation information technologies,' and the standardisation of 'smart manufacturing' systems, including for specific industries (automotive, steel and rail transportation).

The FYPNI sits under the Five Year Plan, China's top-level statement of economic development goals. The 14th Five Year Plan, adopted in March 2021, prioritises development of seven 'key technologies', including the IIoT. The other six categories (including the IoT, listed as a distinct category) are likewise all IT foundational technologies or applications.[23] Policy for the IIoT thus fits within a larger push for wide-ranging and integrated technological

[20] Naughton, B. 'Grand Steerage as the New Paradigm for State-Economy Relations', in Frank Pieke and Bert Hofman (eds), *CPC Futures: The New Era of Socialism with Chinese Characteristics*, NUS Press, 2021, pp105-112.

[21] Jinping, X. (October 2021). 'Some major issues of the national medium- and long-term economic and social development strategy' *Qiushi*. Retrieved from: http://www.qstheory.cn/dukan/qs/2020-10/31/c_1126680390.htm

[22] State Council. (December 2021). '14th Five Year Plan for National Informatisation'. (十四五"国家信息化规划). Retrieved from: http://www.gov.cn/xinwen/2021-12/28/5664873/files/1760823a103e4d75ac681564fe481af4.pdf

advancement, driving progress in national development and international power towards benchmarks set for 2035 and 2049, with the latter being the achievement of 'basic modernisation.'

3. Policies for the 'Industrial Internet' (IIoT) and 'smart manufacturing'

Despite the importance of manufacturing in China, IT uptake by this sector has not kept pace with the consumer-oriented internet platform services economy. For instance, Chinese enterprises' use of cloud computing services in 2018 was estimated at barely 30 percent, compared to 50 percent in the US and over 70 percent in Germany.[24] The lagging state of Chinese manufacturing is reflected in its declining share of GDP, from a peak of 32.45% in 2016 to 27.17% in 2019.[25]

Creating the next-generation manufacturing foundation for future technological leadership was a driving motivation behind the now infamous 'Made in China 2025' (MiC2025) plan adopted in 2015.[26] Directly inspired by Germany's Industrie 4.0, MiC2025 set ambitious goals for technological upgrading and capturing market share in advanced economy sectors, among which was 'high-end computerised machines and robots'.[27] It was accompanied by a detailed technology development roadmap, with goals including the establishment by 2025 of an 'Industrial Internet based on intelligent and connected products and indigenised industrial software'.[28] Also in 2015, the state issued an 'Internet-Plus' plan to promote 'deep integration'

[24] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p8.

[25] Sino-German Cooperation on Industrie 4.0. (19 March, 2021). 'Policy Update: Manufacturing Development in the Government Report and the 14th Five-Year Plan'. Retrieved from: https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/China/policy-update-manufacturing.pdf

[26] State Council. (8 May 2015). 'Notice concerning the issuance of "Made in China 2025"' (国务院关于印发《中国制造 2025》的通知). Retrieved from: http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm

[27] Zenglein, M. and Holzmann, A. (2019). 'Evolving Made in China 2025'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/evolving-made-china-2025. pp19-20.

[28] National Advisory Committee on the Strategy for Building a Manufacturing Superpower. (October 2015). 'Technical Roadmap for the main fields of "Made in China 2025"' (《中国制造 2025》(重点领域技术路线图). Retrieved from: http://www.cm2025.org/uploadfile/2016/0321/20160321015412313.pdf

of the internet throughout society. These initiatives were reinforced in 2016 by policies issued under the 13th Five Year Plan.[29]

Among these was a dedicated policy statement for the IIoT, the 2017 'Guiding Opinions for Deepening "Internet-Plus Advanced Manufacturing" and Developing the Industrial Internet' (IIoT Opinions).[30] This document begins by observing that China is launching its IIoT simultaneously with developed countries, and that international competition in IIoT development is becoming increasingly fierce. It describes the IIoT as 'key infrastructure for the new industrial revolution', characterised by digitalisation, networked systems and machine intelligence. The IIoT is directly linked to China's 'supply side structural reform', with potential utility extending beyond manufacturing to enable 'networked and intelligent' upgrading of various economic sectors.

The IIoT Opinions set a goal for 'initial construction' by 2020 of a low latency, high reliability and wide-area coverage IIoT network infrastructure; an IIoT identification and resolution system; and a dedicated IIoT security system. By 2025, the goal is for 'IIoT network infrastructure covering all regions and industries to be basically completed,' and for China to have produced a small number of internationally competitive IIoT platforms and enterprises. By 2035, the target is for China to have an 'internationally leading IIoT network infrastructure', providing the basis for 'innovation leadership in dominant industries' and for manifesting China's 'international leadership in key fields.' Key to these goals is development of IIoT software platforms, which connect physical objects with software applications and manage the collection, processing, storage and transmission of data.[31]

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[29] Lee, J. (8 December, 2021). 'The internet of things: China's rise and Australia's choices.' Lowy Institute. Retrieved from: : https://www.lowyinstitute.org/publications/internet-things-chinas-rise-and-australias-choices

[30] State Council. (19 November 2017). Guiding Opinions of the State Council on Deepening "Internet + Advanced Manufacturing" and Developing the Industrial Internet, State Council Gazette No. 34 of 2017' (国务院关于深化"互联网+先进制造业"发展工业互联网的指导意见_2017 年第 34 号国务院公报). Retrieved from: http://www.gov.cn/gongbao/content/2017/content_5244870.htm

[31] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. pp14-17.

State-led IIoT development operates within the larger policy framework described above and is (nominally) coordinated through interagency structures. The lead agency is the Ministry of Industry and information Technology (MIIT), which also leads policy implementation for 'smart manufacturing' and has a key role in the general development of IT infrastructure and governance.[32] MIIT oversees the Industrial Internet Special Working Group (IIoT SWG), which sits hierarchically under the top-level interagency Leading Small Group for Building a Manufacturing Superpower, responsible for implementing MiC2025.[33] The IIoT SWG has developed two successive 'action plans' for IIoT development, one for the period 2018-2020 and the next for 2021-2023, that work towards the goals set out in the IIoT Opinions.

Chinese policy for the IIoT is thus inseparable from the strategic goals of building China from a low value-add hub within global manufacturing and IT supply chains into a 'manufacturing superpower' and 'cyber superpower'.[34] This policy direction has been sustained essentially unchanged in the face of growing US pressure on Chinese access to foreign technology and the challenges brought by the coronavirus pandemic. In 2018, an update to the MiC2025 technology development roadmap specified the IIoT as a key focus area.[35] China responded to the pandemic-induced global recession in 2020 with economic stimulus through state-led

[32] Lee, J. (June 2022). 'Cyberspace Governance in China: Evolution, Features and Future Trends'. *Institut français des relations internationales*. Retrived from: https://www.ifri.org/en/publications/notes-de-lifri/asie-visions/cyberspace-governance-china-evolution-features-and-future. p18.

[33] [33] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p21; Zenglein, M. and Holzmann, A. (2019). 'Evolving Made in China 2025'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/evolving-made-china-2025. p29.

[34] Triolo, P. and Webster, G. (25 September 2017). 'China's Strategic Thinking on Building Power in Cyberspace'. DigiChina (Stanford University) . Retrieved from: https://digichina.stanford.edu/work/chinas-strategic-thinking-on-building-power-in-cyberspace/.

[35] Zenglein, M. and Holzmann, A. (2019). 'Evolving Made in China 2025'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/evolving-made-china-2025. p32.

investment in 'new infrastructure', a term that is broadly defined but clearly includes the IIoT as a priority category.[36]

Currently, the key policy for the IIoT is the 'Industrial Internet Innovation and Development Action Plan 2021-2023' (IIoT Action Plan).[37] This sets out eleven 'priority tasks' that include standardisation, developing the bespoke IIoT identification and resolution system (IRS), and enhancing IIoT security. It emphasises product innovation in IIoT 'key general-use technologies,' such as 5G and TSN (time-sensitive networking, enabling low latency), and developing IIoT 'ecosystems' of R&D and supplier firms, thereby involving research institutes, universities and enterprises in collaborative innovation. Among the 2023 goals is basic establishment of a 'unified, integrated and open system of industrial internet standards,' reflecting the general policy drive to put standards development at the centre of China's technological progress and industry building.[38]

MIIT's official commentary on the IIoT Action Plan highlights the following elements (security-related aspects of the plan are discussed in section 5 below):[39]

'building a network infrastructure that supports interconnection of all elements of industry and the whole industrial chain', which is based on standardised systems to homogenise data integration and transfer, and exploits the capabilities of 5G telecoms;

expanding the IRS infrastructure and promoting its use across industry sectors;

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[36] Naughton, B. (2021). *The Rise of China's Industrial Policy, 1978-2020*. Universidad Nacional Autónoma de México. pp88-89.

[37] Ministry of Industry and Information Technology. (January 2021). 'Notice on the Issuance of the Action Plan for the Innovation and Development of the Industrial Internet (2021-2023)' (工业互联网创新发展行动计划（2021-2023年）) . Retrieved from: http://www.gov.cn/zhengce/zhengceku/2021-01/13/content_5579519.htm

[38] See generally Lee, J., Zhang, E., and Creemers, R. (2022). 'China's Standardisation System – trends, implications and case studies in emerging technologies'. Leiden Asia Centre. Retrieved from: https://leidenasiacentre.nl/chinas-standardisation-system-trends-implications-and-case-studies-in-emerging-technologies/

[39] Ministry of Industry and Information Technology. (February 2021). 'Interpretation of the Action Plan for the Innovation and Development of the Industrial Internet (2021-2023)' (《工业互联网创新发展行动计划（2021-2023年）》解读). Retrieved from: http://www.gov.cn/zhengce/2021-02/18/content_5587565.htm

developing IIoT platforms and industry clusters around them, with the specific goal of building 3-5 Chinese IIoT platforms 'with international influence' by 2023;

building an industrial internet data centre and the necessary systems (for example, classification systems and data mining capabilities) to extract value from the accumulated data, while promoting data flow and interoperability between platforms;

government-led efforts to promote a cooperative approach among firms and other actors within industry sectors, given sector-specific complexities of IIoT development.

The IIoT Action Plan also gives significant attention to the needs of small and medium enterprises (SMEs). This aligns with national industrial policy's increased focus on SMEs from the mid-2010s, in tandem with the implementation of MiC2025. The 2017 IIoT Opinions mandate the construction of dedicated network infrastructure for SMEs. Over 10 billion renminbi in subsidies have been assigned out to 2025 to promote development of so-called national grade 'little giant' SMEs, selected based upon financial performance, R&D investment, intellectual property and strategic fit.[40] This focus on SMEs in IIoT development likely stems from observation of the German *Mittelstand*, given the 4IR's association with Germany's manufacturing sector and national economic model, and the salient role of the Sino-German Industrie 4.0 cooperation (discussed below).

SME digitalisation is also prioritised by the 14th Five Year Plan for Smart manufacturing (FYPIM) issued in December 2021.[41] This plan sets a 2025 target for over 70% of manufacturing enterprises with 20+ million renminbi annual revenue to be 'digitised with networking capabilities.'[42] The FYPIM refers to advanced manufacturing development

[40] Brown, A. (24 February, 2022). 'China relies on "little giants" and foreign partners to plug stubborn technology gaps'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/comment/china-relies-little-giants-and-foreign-partners-plug-stubborn-technology-gaps

[41] Ministry of Industry and Information Technology. (28 December, 2021). 'Notice on the Issuance of the "14th Five-Year Plan" for the Development of Intelligent Manufacturing' (关于印发"十四五"智能制造发展规划的通知). Retrieved from: https://www.miit.gov.cn/jgsj/zbys/wjfb/art/2021/art_f3952b4a7d0941609d94262da9891542.html

[42] Sino-German Cooperation on Industrie 4.0. (February 2022). 'Policy Update: 14th Five-Year Plan on Intelligent Manufacturing'. Retrieved from: https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/China/14th_FYP_intelligent-manufacturing.pdf.

policies in the US, Germany and Japan as competition for China in 'the strategic game among the great powers.' However, it also promotes international cooperation – with Germany, Japan and the UK, through the Belt and Road (BRI) Initiative and the BRICS, but omitting the US – in developing advanced manufacturing, including the establishment of cross-border data transfer and intellectual property protection regimes, and encouraging multinational companies and foreign research institutions to build R&D centres, demonstration factories and training centres in China.

Likewise, the IIoT Action Plan's final priority task is 'open cooperation' with the world beyond China. This section includes a target for 2023 of 'establishing exchange and cooperation mechanisms for the Industrial Internet with the European Union and key countries along the Belt and Road.' Foreign-funded enterprises are to be supported 'to participate equally in the innovation and development of the Industrial Internet.' Specifically, the state will support cooperation between Chinese and foreign enterprises to 'develop new business models in the free trade pilot zones, and pilot zones for service industry expansion and comprehensive opening-up.' At the governance level, the Action Plan mandates 'coordination at multilateral and regional levels, and joint exploration into constructing global governance systems in areas such as data flow and intellectual property rights.'

Another notable aspect of the FPYIM and the IIoT Action Plan, and indeed of many other recent industrial policy documents, is their emphasis on 'green' low-carbon development. Reducing energy and resource consumption, and assisting the national goal of carbon neutrality, are basic principles in the FYPIM and reflected in specific objectives (for instance, software development for carbon emissions management). The IIoT Action Plan likewise directs that the digitalisation of China's manufacturing sector must proceed in a way that allows for 'green and safe development.'

Among the main implementation vehicles for these various policies are 'demonstration (or 'pilot') project initiatives' (DPIs). Enterprises or local governments nominate leading-edge projects for state support under DPI criteria. There are dedicated, annually reissued DPIs for smart manufacturing ('integration of new generation IT and manufacturing industry') and for the IIoT. The latter's 2022 iteration prioritises support for IIoT projects that a) are located in extant 'new industry' demonstration zones, or jurisdictions that have proven results in industrial transformation; b) have completed existing processes for acceptance as an IIoT innovation and development project; c) are located in 'old revolutionary areas', or d) have

shown outstanding results in green low-carbon activities, safe production, international cooperation or civil-military integration.[43]

While criterion c) above is probably a concession to the current political climate in China, the other three show an effort to link selection of demonstration projects to specific policy objectives. This is consistent with an apparent, compared to earlier DPI iterations, towards selection of projects based on cross-sectoral applications.[44] The reference to 'international cooperation' also shows that the emphasis upon this in higher-level policy statements is not just rhetorical, but reflects judgment that foreign partnerships remain important, in view of Chinese industry's continued limitations.

Exchanges with firms and research institutions in technologically leading nations, particularly Germany and Japan, are thus seen as a key element of China's IIoT development. But such partnerships are increasingly under pressure, chiefly from the US government and its ever more expansive attempts to retard Chinese technological progress. For example, the sweeping US export controls of October 2022 assert US legal restrictions over US and foreign entities supplying Chinese entities in relation to a range of advanced semiconductors, which are critical components for ICT systems.[45] The prospect of China being progressively cut off from access to cutting-edge foreign technologies and expertise throws into sharp relief Chinese industry's shortcomings and casts doubt on the ambitious policy goals outlined above, despite China's outsized role in global manufacturing.

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[43] Ministry of Industry and Information Technology. (September 2022). 'Notice of the General Office of the Ministry of Industry and Information Technology on the Organization of the Declaration of Industrial Internet Pilot Demonstration Projects in 2022' (工业和信息化部办公厅关于组织开展 2022 年工业互联网试点示范项目申报工作的通知). Retrieved from: https://www.miit.gov.cn/jgsj/xgj/wjfb/art/2022/art_bb17e6873e11489aadb343d4b9e994f4.html

[44] Sino-German Cooperation on Industrie 4.0. (2022). 'Policy Briefing: Demonstration Project Initiatives in China'. https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/China/policy-demonstrator.pdf. p1.

[45] Lee, J. (December 2022). 'Will US Chip Controls Work on China?'. Retrieved from: https://www.thinkchina.sg/will-us-chip-controls-work-china

4. The state of China's IIoT at home and abroad

The Chinese state's effort to bootstrap China's manufacturing sector to global IIoT leadership through indigenously developed technology faces serious obstacles, given the low average level of digitalisation among Chinese enterprises and the high level of dependence on foreign software solutions: in 2019, foreign vendors' share of China's market for high-end industrial software was estimated at over 90 percent.[46] Field research in China during 2018 found that pilot projects which appeared promising on paper did not seem to be delivering quantifiable real-world results.[47]

China's enabling infrastructure deployments are also potentially less 'enabling' of IIoT functions than headline figures might suggest, with questions for example about the number of true 'standalone' private 5G networks in China dedicated to enterprise-specific usage.[48] Development of smart manufacturing and the IIoT is further hindered by shortcomings in China's R&D system, factor market distortions and continued dependence on foreign suppliers for 'core' (or 'foundational') technologies such as semiconductors and machine tools, especially at the most technically sophisticated end of the market.[49]

This situation corresponds with the critical tone and content of Chinese self-evaluations, some examples of which are provided below:

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[46] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p10.

[47] Zenglein, M. and Holzmann, A. (2019). 'Evolving Made in China 2025'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/evolving-made-china-2025. p35.

[48] Blackman, J. (3 August, 2022). 'Five thousand private 5G networks in China? BS! Talking definitions, storms in teacups'. *RCR Wireless*. Retrieved from: https://www.rcrwireless.com/20220803/internet-of-things/five-thousand-private-5g-networks-in-china-bs-plus-definitions-and-a-storm-in-a-teacup

[49] For a brief description of China's place in the global machine tools market, see Lee, J. (2022). 'China Russia Cooperation in Advanced Technologies'. Australia China Relations Institute. https://www.australiachinarelations.org/content/china-russia-cooperation-advanced-technologies-future-global-balance-power-and-limits, pp14-15. On semiconductors, see Lee, J., and Kleinhans, J. (June 2021). 'Mapping China's semiconductor ecosystem in global context: Strategic dimensions and conclusions'. Mercator Institute for China Studies and Stiftung Neue Verantwortung. https://merics.org/en/report/mapping-chinas-semiconductor-ecosystem-global-context-strategic-dimensions-and-conclusions.

- In its 2019 white paper, China's Alliance for the Industrial Internet (AII) assessed that most enterprises were still struggling with basic levels of digitalisation, and not yet generating income from internet platforms.[50]

- A 2020 study published by the Chinese Academy of Engineering found that Chinese enterprises producing machine tools, including next-generation additive and hybrid manufacturing equipment, had 'only just started developing' intelligent systems, and 'have a long way to go before mass production and application can be realized,' with the global market for high-end (computer numerical controlled) tools still dominated by German, Japanese and US companies.[51]

- In March 2021, the director of MIIT described Chinese manufacturing as being in the 'third tier' of a four-tiered global manufacturing pattern, and "30 years away from realising the goal of becoming a 'manufacturing superpower'".[52] He identified obstacles to technological upgrading in flawed market mechanisms (resulting in prices not calibrated to actual supply and demand), inefficient resource allocation for R&D and its insufficient integration with industrial applications, and a shortage of qualified personnel.

- The 2021 evaluation of the IIoT platform sector by CCID, a research institute under MIIT, judged that the 'support industry for the development of China's industrial Internet platforms is weak', with underinvestment in software and a lack of market demand hampering development of core technologies.[53] Platform development is hindered by uneven digitalisation across enterprises, many of which are still reluctant to accept short-term

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[50] Alliance of Industrial Internet. (2019). "Industrial internet Platform White Paper (2019)" [工业互联网平台白皮书 （2019）. http://www.aii-alliance.org/index.php?m=content&c=index&a=show&catid=23&id=673. p.3

[51] Lei, W., and Bingheng, L. (2020). 'Research on the development of machine tool industry in China', *Strategic Study of Chinese Academy of Engineering* 22(2).

[52] Xinhua. (7 March, 2021). 'Miao Wei: Promoting high-quality development of manufacturing' (苗圩：推动制造业高质量发展). Retrieved from: http://www.xinhuanet.com/politics/2021lh/2021-03/07/c_1211054597.htm

[53]China Academy of Electronic Information Industry Development. (31 March 2021). 'China Industrial Internet Platform Development Situation Outlook in 2021' (2021 年中国工业互联网平台发展形势展望). Retrieved from: https://www.enicn.com/Enicn/2021/article_0331/54103.html

production disruptions in the course of upgrading, are risk averse to security issues associated with digitalisation or continue to use foreign-provided industrial software.

There are signs of the Chinese state's re-evaluation and adjustment of policies over time in recognition of Chinese industry's limitations. The 14th FYPIM, for instance, was developed by a notably larger group of ministries than its predecessor plan (which was issued by MIIT and the Ministry of Finance). This is probably meant to better address extensive deficits in China's technological and skilled labour base for pursuing the smart manufacturing and IIoT objectives.[54] The original criteria from 2018 for selecting 'little giant SMEs' included 'potential to develop into a leading international enterprise', but this is not mentioned in the equivalent 2022 document.[55]

Despite this lacklustre picture, there has been quantifiable progress in Chinese industry's IIoT development. A 2019 Fraunhofer study found that by 2015 China had overtaken the US and Germany in patents (numerically, without evaluating for quality) for some 4IR-type technologies, although in categories at the less sophisticated end of the spectrum.[56] Chinese firms have also become globally leading suppliers of IoT systems components, raising security issues for other countries that are discussed in section 5 below. In recent years a notable number of Chinese-proposed standards have been adopted at international standards development organisations such as the ISO and IEC, for example the IoT reference architecture standard (ISO/IEC 30141).[57]

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[54] Sino-German Cooperation on Industrie 4.0. (15 February 2022). 'Policy Update: 14th Five-Year Plan on Intelligent Manufacturing'. Retrieved from: https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/China/14th_FYP_intelligent-manufacturing.pdf.

[55] Ministry of Industry and Information Technology. (26 November 2018). 'Notice of the General Office of the Ministry of Industry and Information Technology on the Cultivation of Specialized and New "Little Giant" Enterprises (工业和信息化部办公厅关于开展专精特新"小巨人"企业培育工作的通知). Retrieved from: https://www.miit.gov.cn/zwgk/zcwj/wjfb/zh/art/2020/art_9dee2248b9244816a2820f91f7886ecb.html

[56] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p39.

[57] Lee, J. (24 June, 2021). 'The Connection of Everything: China and the Internet of Things'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/connection-everything-china-and-internet-things. p10.

One metric for evaluating Chinese firms' international competitiveness in real-world implementation of IIoT systems is the global 'Lighthouse List' of leading manufacturing sites and value chains applying 4IR technologies, which is jointly produced by the consultancy McKinsey and the World Economic Forum (WEF). In 2022, the WEF announced selection of eight new Lighthouse projects located in China.[58] This brought China's total to forty-two, or over a third of the global list.[59] China-located projects constituted around half of the Lighthouse List's 'Advanced Industries' category, covering smart manufacturing and IIoT-type implementations. However, around half these projects were operations in China by foreign (including Taiwanese) firms. This reflects the competition China faces in building domestic IIoT platforms, but also its continued attraction as an R&D and production location as well as a sales market for foreign industry leaders.[60]

Another way to assess the international competitiveness of Chinese-owned IIoT solutions is to look at platforms picked by the state as industrial champions and their international presence. In May 2022, MIIT published a list of 'Cross-Industry and Cross-Domain Industrial Internet Platforms' (2022 leading IIoT platforms).[61] While this may not be an exhaustive list of Chinese IIoT platforms with a high level of technical sophistication and wide utility in application, it is large enough to provide an impression of the sector's development at its leading-edge and global competitiveness.

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[58] World Economic Forum. (2022). 'Industry leaders are driving the adoption of advanced manufacturing technologies'. Retrieved from: https://www.weforum.org/impact/advanced-tecnologies-manufacturing-factories-scaling-innovations/

[59] Huang, Y. (12 October 2022).'5 new Chinese manufacturing sites join WEF lighthouse network'. *Shine.cn*. Retrieved from: https://www.shine.cn/biz/economy/2210121425/

[60] World Economic Forum. (30 March 2022). 'Global Lighthouse Network: The Playbook for Responsible Industry Transformation'. Retrieved from: https://www.weforum.org/whitepapers/global-lighthouse-network-the-playbook-for-responsible-industry-transformation

[61] Ministry of Industry and Information Technology. (18 May 2022). 'Notice of the General Office of the Ministry of Industry and Information Technology on the Announcement of the List of Cross-Industry Cross-Discipline Industrial Internet Platforms in 2022' (工业和信息化部办公厅关于公布 2022 年跨行业跨领域工业互联网平台名单的通知). Retrieved from: https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2022/art_56f15b21b6014c2b889e9fa19e371257.html

These platforms were selected from companies that – according to the eligibility criteria – were already 'large backbone enterprises' in manufacturing or IT, perhaps reflecting the state's reduced expectations for China's SMEs, and its recognition that resources are best directed to firms which already have economies of scale and a critical mass for technological development. Criteria for selecting these 2022 leading IIoT platforms included, for example, the number of industrial software applications based on the platform, the platform's uptake by SMEs, its capacity to support reduction of energy usage and carbon emissions, and its financial sustainability.

One selection criterion was 'the platform's international business expansion capability and international competitiveness, and its ability to provide platform-enabled solutions to foreign enterprises and to bring Chinese technology and Chinese solutions to the international arena.'[62] Figure 1 below provides some examples of these state-endorsed leading Chinese IIoT platforms' international collaborations (the full list of these platforms is provided at Figure 2 below).

Table 1: International collaborations of leading Chinese IIoT providers

Company/Platform	**International collaborations**
Haier COSMOPlat	Firm is a GAIA-X member; active in international standards setting forums; foreign collaborations include SAP, Bosch, Fraunhofer and Aachen University.
Alibaba Cloud	Firm is a GAIA-X member; supports Siemens Mindsphere IIoT platform; collaborations with SAP, Vodafone, French Teleperformance.
Huawei FusionPlant	Firm is a GAIA-X member; numerous foreign collaborations, e.g. supports Bosch IoT Suite and Dassault Systèmes 3DEXPERIENCE platform.

[62] Ministry of Industry and Information Technologyh. (7 March 2022). 'Annex 1: Cross-Industry and Cross-Domain Industrial Internet Platforms in 2022: Requirements for Reporting Capabilities' (附件 1: 2022 年跨行业跨领域工业互联网平台：申报能力要求). Retrieved from: https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2022/art_c9d35297ec014a9ba6bfdbc28d9102e8.html

XCMG Xrea	Foreign collaborations include NXP, SAP, ABB, Advantech (Taiwan); claims customers in a large number of foreign countries.
CASICloud INDICS	Foreign collaborations include Siemens, SAP, Bosch, RWTH Aachen and TU Darmstadt, the last including a collaborative test bed (installed on TU Darmstadt's servers) for European SMEs.
Irootech Rootcloud	Foreign collaborations include AWS, Telenor, ARM and Honeywell; customers in Germany and various developing countries.
UniOrange	Supports Siemens MindSphere.
Yonyou	Branch established in France in collaboration with ATOS.
CMM Humi	Collaboration with SAP for cloud-based services in Chongqing.

While Figure 1 presents an impressive list of activities, many of these involve facilitating service delivery by foreign IIoT platforms (e.g. Siemens MindSphere), or R&D collaborations that have likely benefited the Chinese partner more than the foreign one.[63] Where Chinese IIoT platforms are used abroad, it is unclear to what extent this reflects their technical competitiveness as opposed to advantages from existing business networks, the priority put by foreign partners on access to Chinese markets, Chinese state support for foreign market expansion and other factors.

A notable feature of the 2022 leading IIoT platforms list is the diversity of ownership structures among these companies (Figure 2 below). Two of the most internationally represented platforms (CAISCloud INDICS and Xrea) are owned by entities controlled by Chinese state-owned enterprises (SOEs). China's SOEs are still central to the state's industrial policy priorities, and in 2019 a dedicated IIoT platform for the largest (centrally administered) SOEs was revealed.[64] The lead developer is China Aerospace Science and Industry

[63] On the asymmetrical benefits of German-Chinese collaboration on the IIoT, see Corrocher, N., Mavilia. R., and Giorgio, M. (2018). 'The Sino-German alliance for the fourth industrial revolution: dynamics and policy implications'. *Journal of Economic Policy Reform*, especially at p9.

[64] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p28.

Corporation (CASIC), which controls the CASICloud INDICS platform listed among the 2022 leading IIoT platforms.

However, the two companies from the 2022 list that are heavily represented in the WEF Lighthouse List 'Advanced Industries' category are both private sector firms whose core business directly benefits from pushing the frontiers in IIoT development (Haier and Midea, both home appliance manufacturers). Xrea, which in 2019 was described in Chinese state media as China's only profitable industrial 'Platform as a Service' (PaaS), was also developed by a company (XCMG) that was already successful in manufacturing, and likely benefited from a first mover advantage by launching relatively early (2016) in the context of IIoT platforms' global development.[65] Another Chinese firm in the Lighthouse 'Advanced Industries' category is Sany, which like XCMG is an established machinery manufacturer, and incubated one of the platforms on the 2022 leading IIoT platforms list (Irootech's Rootcloud).[66]

This suggests that, at least when it comes to achieving international competitiveness in IIoT-enabled smart manufacturing, organic industrial development and market incentives operating outside the state's IIoT policy framework have been critical factors. However as described in section 4 below, the state has played an important role in facilitating international R&D collaborations that provided the foundation for these platforms.

Table 2: Ownership character of leading Chinese IIoT platform providers

Company and platform (English names)	**(Chinese company name)**	**Ownership character**
Haier COSMOPlat	海尔卡奥斯物联生态科技有限公司	Mixed (majority private owned)

[65] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p19.

[66] Ibid, p50.

CASICloud INDICS	航天云网科技发展有限责任公	SOE / SASAC / Ministry controlled
XCMG Xrea	徐工汉云技术股份有限公司	SOE / SASAC / Ministry controlled
BONC	北京东方国信科技股份有限公司	Private
Irootech RootCloud	树根互联股份有限公司	Private
INSPUR YUNZHOU	浪潮工业互联网股份有限公司	SOE / SASAC / Ministry controlled
Yonyou	用友网络科技股份有限公司	Private
CMM	重庆忽米网络科技有限公司	Mixed (majority private owned)
Aliyun Cloud Computing	阿里云计算有限公司	Private
Bluetron	浙江蓝卓工业互联网信息技术有限	Private
Shanghai Baosight Software	上海宝信软件股份有限公司	SOE / SASAC / Ministry controlled
Tencent	深圳市腾讯计算机系统有限公司	Private
Huawei	华为技术有限公司	Unclear
Foxconn Industrial Internet	富士康工业互联网股份有限公司	Foreign (Taiwan)
Baidu (Search)	北京百度网讯科技有限公司	Private
GETECH	湖北格创东智科技有限公司	Private
Midea Cloud	广东美云智数科技有限公司	Private
iFlytek	科大讯飞股份有限公司	Private
LUCULENT	朗坤智慧科技股份有限公司	Private
Lanhai IIP	山东蓝海工业互联网有限公司	SOE / SASAC / Ministry controlled
UniOrange	橙色云互联网设计有限公司	Private
Tianrui Xinke	天瑞集团信息科技有限公司	Private

CEC Industrial Internet	中电工业互联网有限公司	SOE / SASAC / Ministry controlled
Asun IIP	江苏中天互联科技有限公司	Mixed (majority private owned)
Geega	广域铭岛数字科技有限公司	Private
CR Digital	华润数科控股有限公司	SOE / SASAC / Ministry controlled
JDT	京东科技控股股份有限公司	Mixed (majority private owned)
Morewis Cloud	摩尔元数（福建）科技有限公司	Private

The foregoing supports a judgment that in development and implementation of IIoT systems, a handful of Chinese firms have demonstrated competitiveness on the international stage, while a larger group provide useable services inside China. For the great mass of Chinese enterprises however, implementing extant IIoT solutions – or even the basic levels of digitalisation needed to enable them – seems to remain a large hurdle. Aiming for broad-based IIoT innovation that is driven mainly by state leadership thus appears to be overly ambitious, although the relentless policy drive to build 'clusters' and 'ecologies' may help uptake of IIoT technologies by reducing entry barriers.

In an economy the size of China's, even a small number of firms operating at the technological frontier can potentially have a large international impact. The salient example here is Haier, now the world's largest home appliances manufacturer. Haier leads China's manufacturing model standards working group (SAC/TC573/WG10) and has contributed to international standards development in forums including the IEEE, IEC and ISO.[67] However even this highly successful example owes much to foreign partnerships, at least in its initial stages of development.

[67] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p39.

5. China-Europe cooperation in IIoT development

All the internationally successful Chinese IIoT platforms described above were developed through international collaborations, with Germany by far the most significant national partner. Haier's COSMOPlat, for example, is based on R&D involving the state-affiliated Tianjin Research Institute for Advanced Equipment and German institutions such as the Fraunhofer Logistics Research Institute and Aachen University's Industry 4.0 training base.[68] Chinese authorities have also courted Japan's IIoT industry alliance (ICV), but have not attained a comparable IIoT partnership with Japan.[69]

The German and Chinese governments signed a memorandum of understanding in 2015 and published a joint declaration in 2016 concerning collaboration in smart manufacturing. Bilateral cooperation under these agreements is institutionalised through the Sino-German Industry 4.0 Cooperation initiative (SGIC), with implementation led by Germany's foreign development agency GIZ and by the China Centre for Information Industry Development (CCID), a research institute under MIIT.[70] This is complemented by bilateral cooperation projects in technical standardisation for smart manufacturing and scientific research into smart manufacturing and smart services, the latter coordinated with China's Ministry of Science and Technology (MoST).[71]

The SGIC provides a framework for bilateral collaborations across 'three pillars': industry cooperation, development of common standards, and science and research. Expert collaboration within this framework aims to develop joint policy recommendations for the two governments' political and industry dialogues.[72] The SGIC has its own 'Lighthouse List' of IIoT implementation projects, which appears to influence MIIT's selection of projects to

[68] Ibid., 46-47.

[69] Matsui, M. (29 March 2020). 'China covets Japan's IoT expertise – missing piece in tech quest'. *Nikkei Asian Review*. Retrieved from: https://asia.nikkei.com/Business/Technology/China-covets-Japan-s-IoT-expertise-missing-piece-in-tech-quest

[70] Corrocher, N., Mavilia. R., and Giorgio, M. (2018). 'The Sino-German alliance for the fourth industrial revolution: dynamics and policy implications'. *Journal of Economic Policy Reform*. p7.

[71] Plattform Industrie 4.0. 'Sino-German Industrie 4.0 Cooperation'. Retrieved from: https://www.plattform-i40.de/IP/Navigation/EN/ThePlatform/Structure-Organization/InternationalCooperation/China/china.html

[72] Ibid.

support under its own IIoT policies.[73] For example, the SGIC is mentioned in the 2021 smart manufacturing DPI, although in the context of a warning to applicants that projects will only be accepted under this bilateral initiative if they engage in substantive cooperation, rather than merely purchasing projects products.[74]

The leading German multinationals in smart manufacturing – notably Siemens, Bosch, SAP and Schneider Electric – have extensive business profiles in China and are doubling down on operations there: Siemens for instance recently opened its first 'digital native' factory in China – planned and simulated entirely in a digital environment before physical construction commenced – which is now the firm's largest R&D and manufacturing centre outside Germany.[75] Increasingly, such operations are R&D intensive: again taking Siemens as an example, the firm operates twenty R&D centres in China, and its artificial intelligence-enabled predictive maintenance platform SiePA was developed in China. Siemens has its own memorandum of understanding with China's macroeconomic planning agency NDRC on cooperation in innovation and application of digital technologies.[76]

These German multinationals are prominently represented among the China-located projects in the WEF Lighthouse List's 'Advanced Industries' category. They also dominate the limited representation of foreign companies in Chinese industry and standards development bodies

[73] Sino-German Cooperation on Industrie 4.0. 'Sino-German Industrie 4.0 Lighthouse Projects'. Retrieved from: https://www.plattform-i40.de/IP/Navigation/EN/ThePlatform/Structure-Organization/InternationalCooperation/China/Leuchtturmprojekte/leuchtturmprojekte.html

[74] Ministry of Industry and Information Technology. (11 August 2022). 'Notice of the General Office of the Ministry of Industry and Information Technology on the Organization of the 2022 Pilot Demonstration for the Integration of New Generation Information Technology and Manufacturing Industries' (工业和信息化部办公厅关于组织开展2022年新一代信息技术与制造业融合发展试点示范申报工作的通知). Retrieved from: https://www.miit.gov.cn/jgsj/xxjsfzs/wjfb/art/2022/art_69bc6e0cd37a401fafbb79b8b22d1624.html

[75] Siemens. 'The Digital Native Factory'. Retrieved from: https://www.siemens.com/global/en/products/automation/topic-areas/digital-enterprise/dex/digital-native-factory.html

[76] Siemens. (March 2022). 'Siemens in China (March 2022 update)' . Retrieved from: https://assets.new.siemens.com/siemens/assets/api/uuid:4fe570e5-f4fc-492b-bdfe-e7f62ae3b45d/corporate-profile-en-202203.pdf

relevant to the IIoT, notably the AII and National Information Security Technical Committee (TC260).[77]

At EU level, the European Commission's DG-CONNECT has discussed the IoT in its annual dialogues with MIIT going back a decade, including publishing joint policy papers on IOT development with the China Academy of Information and Communications Technology, a research institute under MIIT.[78] China is one of three 'global frontrunner innovation markets' (the others being the US and Brazil) served by the Horizon 2020-funded ENRICH network of service centres, which promote European science, technology and innovation links with the target economy.[79]

[77] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p24; Lee, J. (24 June, 2021). 'The Connection of Everything: China and the Internet of Things'. Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/connection-everything-china-and-internet-things. p5.

[79] ENRICH in China: About us (enrichcentres.eu)

6. Security issues, China's IIoT and the foreign perspective

Because the Internet was developed to enable data transfers among mutually trusted parties, its expansion to global scale has brought exposure to cybersecurity risks from a boundless range of malicious or potentially hostile actors. The IoT amplifies these risks by computerising and connecting a growing range of objects, in the physical world, involving large and continuous data transfers that are difficult to monitor and provide vectors for malicious activity.[80] ,The IIoT represents a growing share of this risk profile, as industrial applications increasingly drive IoT growth. Furthermore, the characteristics of IIoT networks require different security approaches – for example, 'closed loop' network segmentation, zero-trust access protocols and more physically robust infrastructure – compared to ICT systems with less demanding workloads, environments and risk profiles.[81]

For the last decade, the Chinese state has been focused on remedying the extensive cybersecurity vulnerabilities brought by the country's massive expansion of ICT devices and infrastructure.[82] Accordingly, the suite of policies for IIoT development have made the security of IIoT networks an equal priority alongside other aspects of their development. The 2017 Outline set a goal for 2025 of establishing 'a more complete and reliable IIoT security system'. Chinese R&D for digital infrastructure that will enable the IIoT, for example 6G telecoms networks, is trying to build in security to the design of these new systems ('endogenous cybersecurity').[83]

China's sprawling cyberspace regulatory regime, which is still being progressively expanded, creates more layers of security impositions on IIoT networks. China's Ministry of Public Security (MPS) administers a 'Multi-Level Protection System' (MLPS) for information systems,

[80] Lee, 'Connection of Everything', 2-4.

[81] How Industrial IoT is Forcing IT to Rethink Networks | TechRepublic

[82] See generally Lee, 'Cyberspace Governance in China'.

[83] Lee, J., Zhang, E., and Creemers, R. (2022). 'China's Standardisation System – trends, implications and case studies in emerging technologies'. Leiden Asia Centre. Retrieved from: https://leidenasiacentre.nl/chinas-standardisation-system-trends-implications-and-case-studies-in-emerging-technologies/. pp22-23.

with tiers that progressively increase the obligations on systems operators.[84] IIoT platforms are likely to be categorised at MLPS level 3 or above, requiring the enterprises operating them to submit to complex regulatory monitoring, testing and certification processes.[85] Extensive reporting obligations to state authorities for 'important data', and opaque decision-making by Chinese authorities on approval of data transfers across the international border under a wide set of potential circumstances, present further challenges for actors that operate IIoT networks in China or exchange data with them.[86]

From a foreign viewpoint, this creates significant risks of Chinese state access to or exploitation of IoT networks in China, or of networks abroad that contain Chinese-made components or run Chinese-developed software. These risks are aggravated by use in IIoT and 5G networks of software from a range of vendors. China's state security agencies, which already have extensive access to data and ICT systems in China under the cyberspace regulatory regime, appear to be closely involved in the government's cataloguing and analysis of IoT cybersecurity vulnerabilities. The frequency of cybersecurity vulnerabilities in Chinese ICT products makes it difficult to assess whether these result from poor industry practices or from deliberate enabling of Chinese state-directed data collection and espionage, but the security implications are comparable.[87]

Even if China does not achieve general IIoT industry leadership, its success in some elements of IIoT systems, especially certain component types, increasingly makes this an unavoidable security issue for foreign governments. By one 2022 estimate, three Chinese manufacturers held over half of global market share in cellular IoT modules, with an extensive presence in

[84] Lee, J. (June 2022). 'Cyberspace Governance in China: Evolution, Features and Future Trends'. *Institut français des relations internationales*. Retrived from: https://www.ifri.org/en/publications/notes-de-lifri/asie-visions/cyberspace-governance-china-evolution-features-and-future. pp23-24.

[85] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p42.

[86] See generally Lee, J. (June 2022). 'Cyberspace Governance in China: Evolution, Features and Future Trends'. *Institut français des relations internationales*. Retrived from: https://www.ifri.org/en/publications/notes-de-lifri/asie-visions/cyberspace-governance-china-evolution-features-and-future.

[87] Chen, J. et al. (2018). 'China's Internet of Things: Research Report Prepared on Behalf of the U.S.-China Economic and Security Review Commission'. Retrieved from: https://www.uscc.gov/research/chinas-internet-things, chapter 3.

foreign markets.[88] In the US, concerns about IoT security and China are centering on the rise of Chinese automakers in the electric vehicle market and potentially in the future autonomous driving market, given the extensive data collection that 'smart' and networked cars will conduct. The Chinese state itself has restricted to some degree the use and movement of Tesla vehicles in China due to similar security concerns.[89] In countries where companies and industrial infrastructure are becoming integrated with Chinese production systems, such concerns will focus on IIoT networks and industrial espionage.

Risks from an extensive Chinese presence in the global IoT may come to dwarf the implications of including Huawei equipment in 5G networks, which has already been the source of much international tension. Many developing countries seem willing to accept such risks – including large economies like Indonesia, which is now being cultivated by European governments as an alternative market to China and a key supplier of nickel for large capacity batteries[90] - meaning that engagement in their economies will likely increasingly involve exposure to Chinese digital networks and technology.[91] The rising politicisation of international trade and technology networks will be supercharged by the rise of the IoT, confronting policymakers with more hard tradeoffs between prosperity and security.

[88] Drew, A. (10 August, 2022). 'Chinese technology in the 'Internet of Things' poses a new threat to the west'. *Financial Times* 2022 https://www.ft.com/content/cd81e231-a8d3-4bc0-820a-13f525a76117

[89] Toh, M. (23 June, 2022). 'Tesla is still battling spying suspicions in China'. *CNN*. Retriebved from: https://edition.cnn.com/2022/06/23/business/tesla-barred-china-suspicions-intl-hnk/index.html

[90] Priyandita et al. (11 July, 2022). 'Localization and China's Tech Success in Indonesia'. Carnegie Endowment for International Peace. Retriever from: https://carnegieendowment.org/2022/07/11/localization-and-china-s-tech-success-in-indonesia-pub-87477

[91] See generally Lee, J. (8 December, 2021). 'The internet of things: China's rise and Australia's choices.' Lowy Institute. Retrieved from: : https://www.lowyinstitute.org/publications/internet-things-chinas-rise-and-australias-choices

Conclusions and recommendations

The IIoT offers a path to a 4IR future that China's leaders seem to view as a silver bullet for the nation's developmental and demographic problems. The fact that these promised transformational benefits have to date only limited manifestations, even in the most industrially advanced economies, has apparently not changed this view. China's entire 'innovation-led development strategy' is a gamble on the idea that emerging technologies will eventually produce synergies on a scale that will catapult first movers to global economic leadership. Through state-led development of technologies like the IIoT, 'The Chinese are attempting to position themselves so that, when the revolution comes, they will have the skills to be a half step ahead, or at least not behind.'[92]

Beijing's vision for this 4IR-enabled future is not one of autarky, but rather of leadership in an integrated world economy not fundamentally different from that of the past quarter century, except that China's place within the hierarchy has changed. As political pressures abroad have mounted for economic and technological 'decoupling' with China, Beijing's response has simply been to double down on its existing strategy. As put in an authoritative 2021 commentary on the 14th Five Year Plan attributed to Xi Jinping, the goal is to 'tighten the international industrial chain's dependence on China.'[93]

However, US policy is now starting to target whole segments of Chinese industry 'decoupling' in ways that leave no room for maneuver. In October 2022, the Biden administration instituted far reaching export controls restricting China's access to semiconductors and the technology required to make them. Although nominally targeted at leading-edge chips, the rules' drafting means they could potentially apply to a much wider range of semiconductors, covering the chips required to support many IoT functions. US allies are under pressure to replicate these controls, and Washington's expectation of such cooperation can be expected to increasingly apply to exchanges with China wherever 'strategic' technologies are involved.

[92] Naughton, B. (2021). *The Rise of China's Industrial Policy, 1978-2020*. Universidad Nacional Autónoma de México. p95.

[93] Jinping, X. (October 2021). 'Some major issues of the national medium- and long-term economic and social development strategy' *Qiushi*. Retrieved from: http://www.qstheory.cn/dukan/qs/2020-10/31/c_1126680390.htm.

Collaborations with Chinese actors directly linked to the defence industrial base are especially likely to attract attention.

For example, the German government is jointly supporting with China's MoST a research project covering the functionalities of CASICloud INDICS, one of China's leading IIoT platforms which was originally developed in close partnership with SAP and Siemens.[94] CASIC, the SOE that controls this platform, is one of the leading institutions in China's defence sector and outer space program, and although is not yet on the US entity list, several of its affiliates are. Given that China's selection criteria for pilot IIoT projects includes promotion of civil-military integration, potentially no such IIoT collaboration will be safe from political pressure for cessation, justified by the prospect of China's rise as a peer competitor to the US in the industrial foundations of military capability.

European policymakers face hard choices, as the global rise of industrial policy and factor prices erodes European firms' competitiveness and drives them to look for opportunities outside the EU.[95] European industry leaders have benefited from involvement in the development of the world's second largest economy and maintain clear advantages in their 'terms of engagement' with Chinese actors in certain technological systems, including the IIoT. But even current institutional settings offer warnings of future marginalisation. In the committee structure and working group structure of China's AII, only four foreign firms (SAP, Siemens, Schneider Electric and GE) are represented, with a proportionately very small share of representatives.[96]

Policymakers face the reality that some of Europe's leading corporate actors in the IIoT – the German multinationals at the forefront of the industrial systems and automotive sectors – are committed to partnership with China. In the view of Siemens' CEO, 'without China, diversification is not possible', given that R&D and expansion into new markets is

[94] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p13.

[95] Financial Times. (20 November, 2022).'European industry pivots to US as Biden subsidy sends 'dangerous signal'. Retrieved from: https://www.ft.com/content/59a8d135-3477-4d0a-8d12-20c7ef94be07

[96] Kupfer, K., et al. (2020). 'China's digital platform economy: Assessing developments towards Industry 4.0', Mercator Institute for China Studies. Retrieved from: https://merics.org/en/report/chinas-digital-platform-economy-assessing-developments-towards-industry-40. p24.

increasingly funded from operations in China.[97] But while leading European multinationals benefit from business with China, the implications for European SMEs – which are prioritised in the EU's own economic and technology policy – and the larger European economy may be less positive.[98]

Given political tensions with China and the far-reaching powers of the Chinese security state, cybersecurity risks must also be dealt with when making choices about integration with China's evolving IoT and the economic systems built around it. These risks are already viewed by some commentators as severe enough to justify the isolation of liberal democracies not just from the digital networks of China, but from those of all countries that allow Chinese participation in their digitised infrastructure and economic systems.[99] European interests are unlikely to be defined in ways that reach so drastic a conclusion. But managing such risks – and not only with respect to China – is critical to realising the promises of a Fourth Industrial Revolution enabled by the IIoT.

[97] Olk, J. and Peer, M. (14 November 2022). 'Siemens-CEO Busch: Ohne China ist Diversifizierung nicht möglich' (Siemens CEO: Diversification is not possible without China). *Handelsblatt*. Retrieved from: https://www.handelsblatt.com/politik/international/interview-siemens-ceo-busch-ohne-china-ist-diversifizierung-nicht-moeglich/28806728.html

[98] Sebastian, G. (27 October 2022). 'The bumpy road ahead in China for Germany's carmakers' Mercator Institute for China Studies. Retrieved from: https://www.merics.org/en/report/bumpy-road-ahead-china-germanys-carmakers

[99] See e.g. Demchak, C. (2018). 'Three Futures for a Post-Western Cybered World'. *Military Cyber Affairs* 3(1), Article 6; and Clarke, R. and Knake, R. (Sep/Oct 2019). 'The Internet Freedom League: How to Push Back Against the Authoritarian Assault on the Web'. *Foreign Affairs*. Retrieved from: https://www.foreignaffairs.com/articles/2019-08-12/internet-freedom-league.