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China's Manufacturing Innovation Centers

A Benchmarking Report for the Manufacturing USA Network

NIST Office of Advanced Manufacturing

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A Benchmarking Report for the Manufacturing USA Network

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Abstract

This review of China's Manufacturing Innovation Centers (MICs) describes the status of the country's flagship manufacturing innovation program. At least 33 MICs have been established to date, suggesting that China is within reach of its goal of 40 MICs by 2025, as stated in the "Made in China 2025" national strategy. This review discusses the motivation, structure, and results of the implementation of the Manufacturing Innovation Centers so far, particularly with respect to their 14th Five-Year Plan, and compares China's approach to manufacturing innovation with that of the Manufacturing USA program and Germany's Fraunhofer Institutes. China views strategic investment in critical advanced manufacturing technologies as a focal point for furthering national interest and technical leadership.

Keywords

China industrial centers. Manufacturing Innovation. Manufacturing USA. Manufacturing Innovation Center. Made in China 2025. Advanced Manufacturing.

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Acknowledgments

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Executive Summary

The Chinese Manufacturing Innovation Centers (MICs) were initiated in 2015 in response to the U.S. Manufacturing USA program, drawing inspiration also from Germany's *Industrie 4.0.* [1, 2] China established the centers to be distinct vehicles for manufacturing innovation with the end goal of reaching world leadership in 10 key target industry sectors. The centers would receive central government support to become a technical hub. The center then connects and co-locates with state key laboratories and other resources to form manufacturing ecosystems for the key industries.

"Made in China 2025," released in 2015, further solidified the MIC plans. Made in China 2025 was an initiative to comprehensively strengthen the Chinese industry, starting with a 300 billion U.S. dollar (USD) investment over 2016-2020. [3] The plan outlined a path to approach 80 % production by domestic supply chains by 2025 in a range of industries that rely on advanced manufacturing technologies, including aerospace, semiconductors, robotics, pharmaceuticals, and electric vehicles (EVs). The plan identified a number of technology barriers for each manufacturing sector, which became the technical focus of each MIC. As such, the MICs play a strategic role in establishing an innovation hub for each enabling technology.

China has made rapid progress toward its goals. The first MIC was established in 2016, and as of early 2025, China had created at least 33 MICs. The China MIC model adapts elements from the Manufacturing USA design, with environments for industry and academia to collaborate on applied research on promising advanced manufacturing technologies.

Topics for the centers are determined by China's Ministry of Industry and Information Technology (MIIT) and are similar to high critical technology priorities in other manufacturing countries. All topics are consistent with the 10 target industry sectors identified in the Made in China 2025 initiative. Investments in several key industries, such as electric vehicles and renewable energy/photovoltaics, have led to dramatic increases in market share for these technologies. The extent of success in other crucial technologies, such as biopharmaceutical manufacturing, is more difficult to document.

China's 14th Five-Year Plan, spanning 2021 to 2025, continued this large-scale investment. [4] Manufacturing again was a major topic, with a focus on reducing foreign dependency on critical components such as integrated circuits, as well as global leadership in advanced manufacturing. With implications of the growth of these innovation programs on production and foreign trade, the Chinese Manufacturing Innovation Centers are moving forward in key technology focus areas of pharmaceuticals, renewable energy, and semiconductors.

1. Introduction

The Manufacturing USA Institutes were initiated in 2014 as a strategic response to global economic shifts, where supply chains for advanced technology products moved overseas, threatening U.S. leadership in advanced manufacturing. While the U.S. had remained a leader in innovation and research and development (R&D), there was an urgent concern about the risk of a declining competitive position. Ten years later, the Manufacturing USA institutes continue to convene business competitors, academic institutions, and other stakeholders to test applications of new technologies, create new products, reduce cost and risk, and enable the manufacturing workforce with the skills of the future.

China immediately responded with its own plan for Manufacturing Innovation Centers (MICs) with a similar goal to become a world leader in advanced manufacturing and ensure self-sufficiency in critical technology areas. The Manufacturing Innovation Centers are a centerpiece of China's manufacturing innovation program within their Made in China 2025 national strategy and 14th Five-Year Plan. While it is difficult to find data separating the impact of the innovation centers from the wider Chinese innovation and manufacturing strategy, the change in the balance of worldwide manufacturing is undeniable. As quoted by the Special Competitive Studies Project (SCSP): [5]

In 1980, the United States manufactured over 40 percent of global high-technology goods, compared to just 18 percent today. Meanwhile, the People's Republic of China (PRC) has cultivated unrivaled high-tech industrial production capacity and is responsible for nearly 30 percent of total global manufacturing output.

As of 2024, China leads in the majority of manufacturing sectors, producing more than the U.S. in 9 of 11 total subsectors for global manufacturing (Fig. 1). At the current growth rates, this gap is likely to widen, as China has had a five-year compound annual growth rate of 5.3 % while the U.S. compound annual growth rate is estimated to be around 1.5 % (Fig. 2). [6]

This report summarizes the function and impact of China's manufacturing innovation strategy, outlines the format of the MICs, and highlights similarities and differences with Manufacturing USA. Very little information is publicly available concerning the details of how MICs are organized and operated. This report is based on information from visiting selected MICs during two benchmarking trips, along with available public information. Accordingly, an important caveat to note is that the findings may not be common to all MICs and that the institute model may have evolved for the latest MICs.

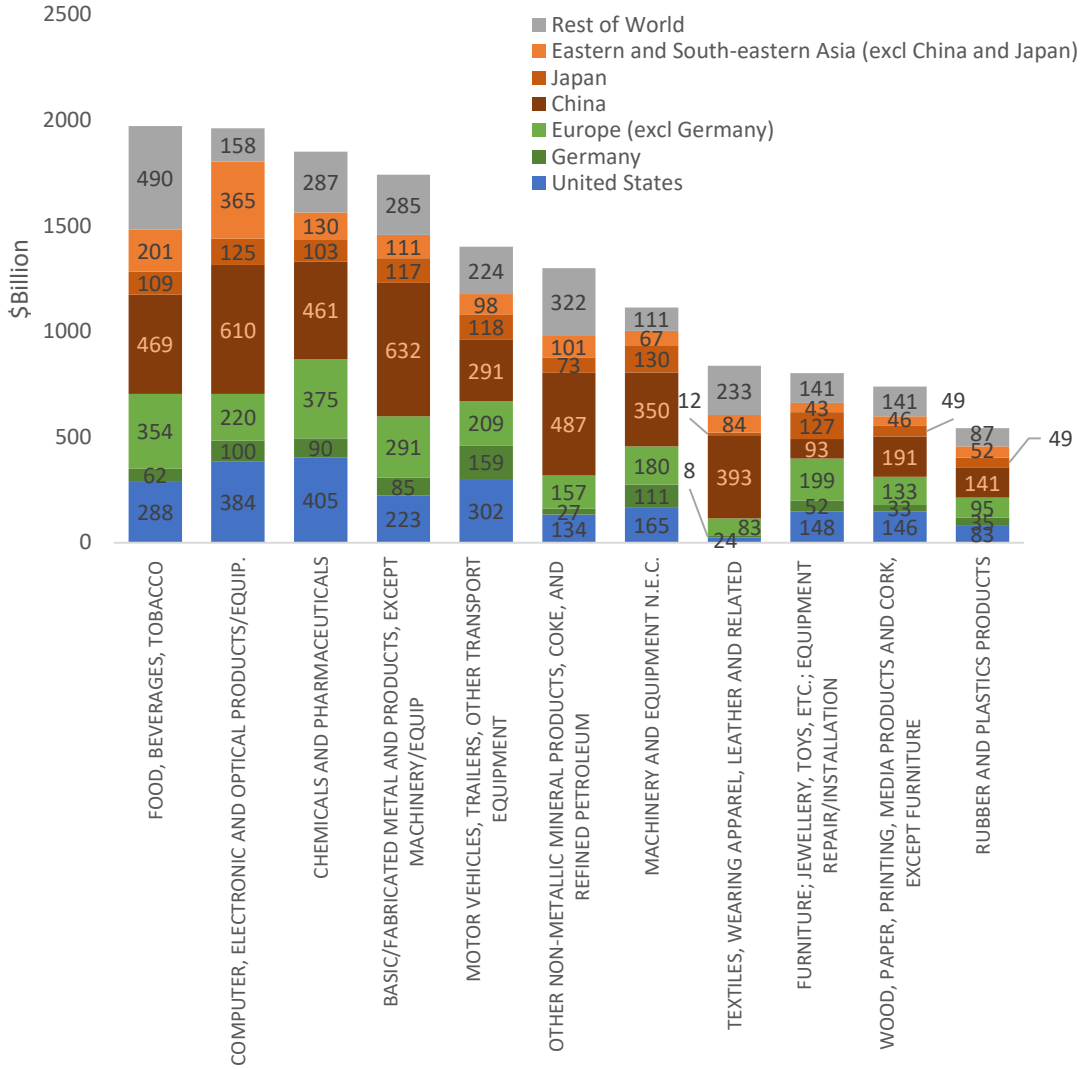

Figure 1: Global Manufacturing Value Added by Industry, by Country/Region

Data Source: Organisation for Economic Co-operation and Development (OECD). (2024). Trade in Value Added (TiVA). [7]

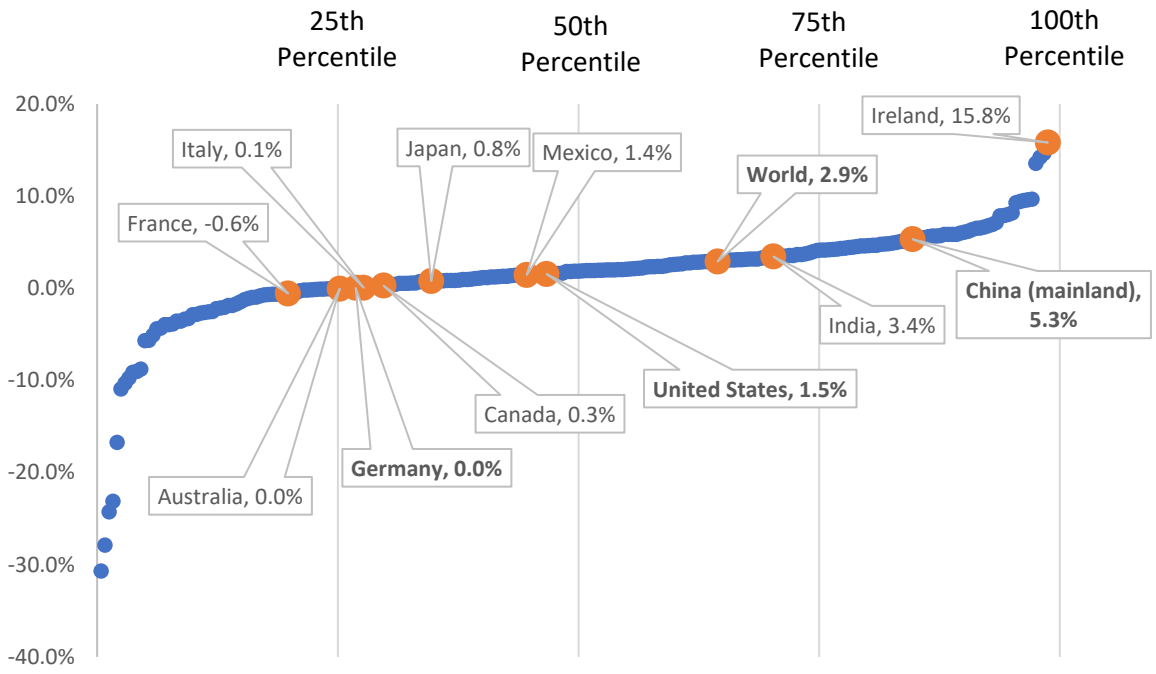

Figure 2: National 5-Year Compound Annual Growth, by Country (2017 to 2022)

Data Source: United Nations (U.N.) Statistics Division. (2024). "National Accounts Main Aggregates Database." [8]

2. Chinese Innovation Plans

2.1. "Made in China 2025" and the Manufacturing Innovation Centers

"Made in China 2025" is an initiative to comprehensively strengthen Chinese manufacturing and achieve global leadership in 10 strategic industry sectors, starting with a 300 billion USD investment over 2016-2020. [3] This is a top-down national strategy by the Chinese Ministry of Industry and Information Technology (MIIT), one of 26 cabinet-level Departments of the State Council, invoking the mobilization and participation of all sectors of society and the integration of civil and military resources. The goal was to become nearly self-sufficient by 2025 in important advanced manufacturing industries, including aerospace, computer chips, robotics, pharmaceuticals, and electric vehicles, where it was well positioned to become the world leader. Manufacturing was one of the six key policies addressed in China's 13th Five-Year Plan (2016-2020) with the goal of becoming "a strong country in manufacturing."[9]

A significant part of the plan was the creation of Chinese "manufacturing innovation centers," or MICs, initiated in 2015, stimulated by U.S. developments with Manufacturing USA. These centers focus on the technology barriers for the 10 strategic industry sectors and serve as the technical nexus for hubs of innovation and development. At the same time, the U.S. Advanced Manufacturing National Program Office, which serves as the interagency program office for the Manufacturing USA network, became a subject of research by the Chinese Academy of Social Sciences (CASS) in Beijing. CASS is an economic and social science think-tank of about 5,000 staff members concerned with national policy. To complement the central government's investments, each of China's 22 provinces, five autonomous regions, and four municipality governments also established manufacturing innovation centers.

2.2. 14th Five-Year Plan

Continuing this effort, China released its 14th Five-Year Plan (2021-2025) [4] with a continued focus on domestic manufacturing, specifically addressing the reduction of foreign dependency on critical components. For example, technology and capacity upgrades are key to China's core strategy for self-sufficiency in semiconductors; with the 14th Five-Year plan, foundry capacity is projected to expand by 40 %, and the fabrication process is expected to advance to 7 nanometers (nm). [10] At the start of the plan period, China had limited capabilities in semiconductors, with 0 % of the most advanced process technology at the < 10 nm level and only 3 % of the next category at the 10-22 nm level; however, as of 2019, it had 19 % of the 28-45 nm and 23 % of the earlier generation process technology. [11]

The 14th Five-Year Plan also included multiple references to the technology innovation centers (Table 1). These references fall into three categories. *First*, the centers serve a similar role to Manufacturing USA Institutes in driving technological innovation and accelerating product development. *Second*, the centers serve as dedicated hubs to bring together research and industry and contribute to regional economies. *Third*, the innovation centers contribute to societal norms and growth.

Table 1: 14th Five-Year Plan References to Innovation Centers [4]

Category 1: Technology Innovation	Part Two, Article IV, Section 1: Consolidate and optimize science and technology (S&T) resource allocation. "*We will optimize and upgrade innovation bases including national engineering research centers and national technology innovation centers. We will promote an optimal allocation of scientific research power and the sharing of resources among research institutes, institutions of higher education, and enterprises. We will support the development of new types of innovative entities, […] and promote the diversification of investors, the modernization of management systems, the marketization of operating mechanisms, and the flexibility of employment mechanisms."* Part Two, Article IV, Section 4: Establish major technological innovation platforms. *"We will support the formation of international S&T innovation centers in Beijing, Shanghai, and the Guangdong-Hong Kong-Macau Greater Bay Area, build comprehensive national science centers in Huairou in Beijing, Zhangjiang in Shanghai, the Greater Bay Area, and Hefei in Anhui, and support the construction of regional S&T innovation centers in places with the necessary prerequisites."* Part Two, Article V, Section 2: Support R&D on general purpose and basic industrial technology. *"We will concentrate efforts to integrate and upgrade a number of key general purpose technology platforms, support the joint construction of national industrial innovation centers by industry-leading enterprises in partnership with institutions of higher education, scientific research institutes, and upstream and downstream enterprises in the industry, and undertake major national scientific and technological projects."*
Category 2: Regional Hubs	Part Three, Article VIII, Section 1: Strengthen the construction of industrial foundation capacity. "*We will improve the industrial foundation support system, deploy a number of national manufacturing innovation centers in key areas, improve the national quality infrastructure, build production and application demonstration platforms and public service platforms for basic industrial technology such as standard measurement, certification and accreditation, inspection and testing, and test verification, and improve databases for industrial foundations such as processes and technologies.*" Part Nine, Article XXXI, Section 1: Accelerate the coordinated development of Beijing-Tianjin-Hebei. "*We will improve the basic research and original innovation […] capabilities of the Beijing Science and Technology Innovation Center, give full play to the pioneering role of the Zhongguancun National Independent Innovation […] Demonstration Zone, and promote the deep integration of the Beijing-Tianjin-Hebei production chains and innovation chains*." Part Nine, Article XXXII, Section 1: Promote the development of the western region to form a new pattern. "*We will promote the construction of the two-city economic circle in the Chengdu-Chongqing area, create an important economic center, S&T innovation center, a new bastion […] of reform and opening up, and a high quality-of-life place with national influence, improve the construction level of the Guanzhong Plain urban agglomeration, and promote cooperation and interaction between Northwest China and Southwest China*."
Category 3: Societal Norms	Part Ten, Article XXXVI, Section 3. Table 13: "Socialist cultural prosperity and development projects: 06: Construction of major cultural facilities: '*a national cultural heritage S&T innovation center'*" Part Thirteen, Article XLIV, Table 17: National health protection projects: "*We will build about 20 national TCM (note: Traditional Chinese Medicine) heritage and innovation centers, about 20 TCM and Western medicine collaboration flagship hospitals, about 20 TCM epidemic prevention and control bases, and about 100 key hospitals with TCM characteristics, forming a group of superior TCM specialties*."

2.3. China's Progress in Advanced Manufacturing & Related Industries

The key industries targeted for self-sufficiency and global leadership in the Made in China 2025 initiative (Fig. 3) align with critical and emerging technologies first identified by the White House Office of Science and Technology Policy in 2020, specifically advanced computing, advanced engineering materials, advanced manufacturing, biotechnologies, automated robotics, as well as new energy and aerospace technologies. [12] China is heavily investing in manufacturing; the Made in China 2025 initiative is a hallmark program for Chinese industry to gain competitive leadership in advanced manufacturing technologies, such as attempted gains in biotechnology and electric vehicles (EVs). [13] In 2024, China's investments in manufacturing grew by 9.2 %, with increasing investments in the following sectors: rail, shipping, and aerospace (+34.9 %); non-ferrous metals smelting and processing (+24.2 %); metal products (+16.6 %); and information technology (+12 %). China also announced a third investment phase (47.5 billion USD over five years) of its semiconductor fund. [14]

China's approach to selecting the chartered technology for each MIC emulated a market-driven approach to create a "technology pull" from the strategic industry sectors rather than a "technology push" of research centers. For each of the strategic industry sectors, the critical and enabling technologies were identified, then MICs were established (Fig. 6). A particular technology may be relevant to multiple industry sectors, but there is a clear rationale linking each institute to the national strategy. For example, the first MIC was established to focus on the technological barriers to significant improvements in EV batteries. Recognizing that research in lightweight materials and intelligent/connected vehicles was further needed to advance battery functionality, additional MICs were located in the same region. MICs thus followed a technical portfolio approach linked to the national strategy and implemented to seed innovation hubs.

Along with technological leadership, a priority for Made in China 2025 is developing the domestic supply chain, and thus reducing imports, for key manufacturing components, as shown in Fig. 4 below. The manufacturing innovation centers are just one piece of China's industrial policy strategy for achieving those goals. As outlined in a Congressional Research Service report [15], tactics include tax, trade, and investment measures; forced joint ventures and partnerships; government subsidies; foreign acquisitions; technology licensing and equipment; and talent recruitment and training.

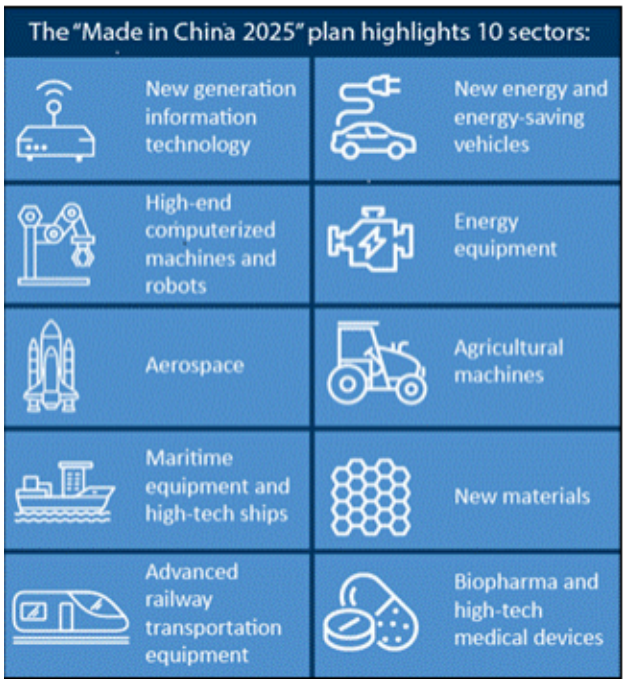

Figure 3: China's Industrial Priorities (2015-2025)

Source: Notice of the State Council on Issuing Made in China 2025, PRC State Council. (2015). No. 28. [16]

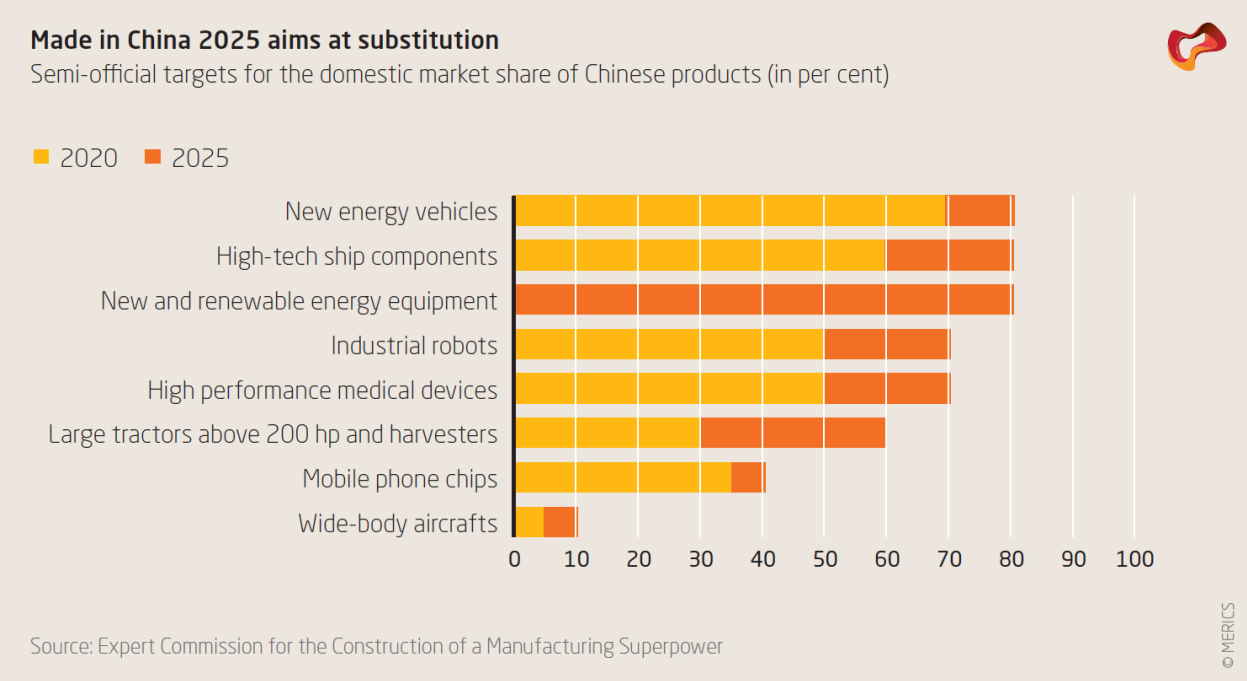

Figure 4: Selected Made in China 2025 Domestic Content Goals

Source: Jost Wubbeke, Mirjam Meissner, Max J. Zenglein, Jaqueline Ives, and Bjorn Conrad, "Made in China 2025: The making of a high-tech superpower and consequences for industrial companies." *Mercator Institute for China Studies (MERICS)*. (December 2016). [17]
Excerpt source: "Made in China 2025: Global Ambitions Built on Local Protections." *U.S. Chamber of Commerce*. [18]

3. China's Manufacturing Innovation Centers

China's launch of the Manufacturing Innovation Centers draws parallels to other major industrial nations, including both the U.S. and Germany, with adaptations to fit China's system. [19]. These public-private partnership consortia consist of members from industry, academia, and other entities and represent each country's leading central government program to stimulate innovations in manufacturing technology to improve productivity in advanced manufacturing.

The Chinese MIIT's *Manufacturing Innovation Center Construction Project Implementation Guide (2016-2020)* [20] provides guidance on the broad, coordinated implementation of the innovation center program. This guide represents some of the few details available regarding how MICs are organized and operated.

Each Manufacturing USA institute is run as a not-for-profit entity with a large membership group, typically more than 100 manufacturing companies and research universities, with membership agreements. China's MICs, in contrast, appear to be structured as for-profit entities, usually with 10-20 equity owners.

The Implementation Guide outlines the main tasks for MICs in areas that directly parallel Manufacturing USA, as well as in areas that go further, namely:

- R&D of frontier industrial and common key technologies,
- Establish industry-university-research collaborative innovation mechanisms,
- Strengthen the protection and utilization of intellectual property (IP) rights,
- Promote the commercial application of scientific and technological achievements,
- Strengthen the guiding and guaranteeing of standards,
- Serving the masses for entrepreneurship and innovation,
- Build a multi-level talent team, and
- Encourage international cooperation.

There are some significant differences tailoring the program to opportunities unique to China's mix of central control with some market economy dynamics. Important to the Manufacturing USA institute model is robust open engagement of industry – and academia – on applied research projects. MICs are structured to ensure industry and academic engagement through some directed mechanisms different from the open consortia model of Manufacturing USA.

- The MIC model appears to include a for-profit institute approach with a small group of equity owners. That partnership group can include the government. The partners fund the MIC, direct the project plans, and own institute-developed IP.
- The MIC model ensures linkage with academia by the engagement of "State Key Laboratories" in centers. Every leading engineering university in China has one or more

State Key Laboratory designations. Moreover, a MIC may be based on a State Key Laboratory or government lab. [21]

- The MIC can be in competition with other technology leaders in China, including domestic businesses or research labs.
- The *Manufacturing Innovation Center Construction Project Implementation Guide (2016-2020)* [20] provides guidance on the broad, coordinated program implementation using central and local government resources along with private support. Such broad public and private financial support may include:
    - Diversified financing channels,
    - Financial support for technology innovation infrastructures,
    - Fiscal and tax policy support,
    - International cooperation, and
    - Workforce training.

3.1. Selection Criteria for a Center's Research Focus

The Chinese MICs' research focus is selected by the government, specifically, MIIT as the lead ministry. Consequently, Made in China 2025 organization is within the MIIT office, where the Ministry of Education also resides. The Vice Minister of MIIT is also the director of the Made in China 2025 office, indicative of the very high level of this office and its broad oversight of the country's research and education.

Made in China 2025 describes "projects" or steps to establish a new Manufacturing Innovation Center. First, MIIT develops a topic of priority to the nation, then publishes that topic with five guidelines. The competitions are open to all. Applications typically are approximately 200 pages and are evaluated by a review panel before awards are announced.

Key leaders from MIIT and the Chinese Academy of Engineering (CAE) are often on the review panels to select and approve new institutes. In general, topics support the 10 priority industry sectors identified in Made in China 2025. Given that a bottleneck for China has been its dependency on foreign sources for core components, many topic areas have been designated to address this vulnerability, particularly in the foundational fields of new materials, semiconductors, and key components for advanced machinery and machine tools, in addition to maintaining their competitive edge in core and future technologies such as batteries, artificial intelligence, and next-generation information technology (IT). [22] See Appendix A for a table and map listing the currently known MICs.

Topics within each MIC are developed by members of the manufacturing leadership who were also architects of Made in China 2025. The concepts are further developed by working with leading institutes in the country. Competition descriptions might be as short as one page, and nominally anyone can apply. In practice, if one organization is widely recognized as being the best in the country, then there may be only the one applicant. In other cases, there may be more. For example, the large state laboratory, China Academy of Machinery Science and

Technology, widely known to be the best in metals processing, was the sole applicant for the Lightweight Materials Technology Institute; in contrast, the National Robot Innovation Center had three proposals submitted. Those developing concepts for the competition can also be applicants.

3.2. Comparing China's MICs to Manufacturing USA and Germany's Fraunhofer Institutes

3.2.1. Structure

Manufacturing USA has different federal agencies as institute sponsors, and each institute is run by an industry-led consortium. The Advanced Manufacturing National Program Office convenes the network of Manufacturing USA institutes.

Germany's Fraunhofer Institutes operate as somewhat decentralized entities but are structured to allow centralized management through the Fraunhofer Society, or "Fraunhofer-Gesellschaft." The central leadership is the Presidential Council of the Fraunhofer Society, which contains the Executive Board and Group Chairs. The Executive Board members are appointed by the Senate, which is advised by the Scientific and Technical Council, and can be discharged by the General Assembly. The Group Chairs in the Presidential Council are delegated by the nine Fraunhofer groups, representing the high-level topical areas for the 76 Fraunhofer Institutes. [23]

Finally, China's MICs have a single central government providing common direction. This direction from the central government ensures that the program will be embraced and invested in across the nation at all levels by all relevant entities, resulting in a rapidly progressing MIC program. The central government has a great deal of influence relative to corporations, and all levels of government and corporations work to meet the Chinese government's expectations. In addition, national pride appears as a strong driver throughout the country. Sources state that China has met more than 86% of target key performance indicators for the 260 listed objectives in the overarching Made in China 2025 agenda. [24, 25]

3.2.2. Intellectual Property (IP) Management

There are also several differences between the three countries regarding intellectual property management and ownership. In Manufacturing USA, IP is generally handled on a project-by-project basis, and the institute itself is responsible for its IP management plans. In the German Fraunhofer Institutes, generally, the Fraunhofer Society owns IP in the case of an entity using a Fraunhofer facility, but exceptions are made for certain partnerships and agreements.

In China, projects are prioritized by the consortium, and project teams conduct pre-competitive research. The outcome benefits the institute, and project IP is generally owned by the project team. The equity owners may be one or two large state-owned or public companies, a few small companies with key technologies, and central and local governments. The equity partners direct the project plans and own any institute-developed IP for their own commercialization. It is this equity group that is responsible for the substantial investment and capitalization of each MIC.

3.2.3. Financing

Like the U.S. and German counterparts, China's MICs are organizations tasked with advancing technologies for the benefit of a particular industry and are financed through a mix of federal and non-federal funding. In both the Manufacturing USA program as well as Germany's Fraunhofer Institutes, the federal government invests in the consortia with the expectation that the consortia must attract matching funding through industry and other sources. [26]

Compared to Manufacturing USA, China has invested far greater resources in the MICs and the broader industrial base supporting the MICs, both from MIIT and those marshaled by the expectations underlying Made in China 2025 and detailed in *The Manufacturing Innovation Center Construction Project Implementation Guide, (2016-2020)*: [27]

> "*The relevant projects and national science and technology planning projects in 'Made in China 2025' give priority to the declaration projects of national manufacturing innovation centers and provincial manufacturing innovation centers."* [20]

Additionally, the 14th Five-Year Plan [4] specifically states:

> "*We will improve the industrial foundation support system, deploy a number of national manufacturing innovation centers in key areas, improve the national quality infrastructure, build production and application demonstration platforms and public service platforms for basic industrial technology such as standard measurement, certification and accreditation, inspection and testing, and test verification, and improve databases for industrial foundations such as processes and technologies.*"

Central, provincial, and local governments in China are expected to support the program and lead the MIC for the common good at the local and national levels. *The Manufacturing Innovation Center Construction Project Implementation Guide (2016-2020)* provides detailed technical and financial guidance to ensure success; in addition to the central government, support includes "establishing diversified financing channels," increased financial support for technology innovation infrastructure, "increased fiscal and tax policy support," international cooperation, and "strengthening personnel training."

The first two Chinese institutes were awarded in 2016, and as of March 2025, at least 33 MICs appear to be active. Manufacturing USA, which received Congressional authorization in late 2014, has 18 active institutes to date. Germany's Fraunhofer Institutes began in 1949, and to date, there are 76 institutes. Table 2 below compares these three manufacturing nations' flagship manufacturing innovation programs, highlighting the differences in government investment and priorities in funding manufacturing, indexed to the U.S. manufacturing gross domestic product (GDP).

Table 2: Manufacturing Innovation Programs in the U.S., China, and Germany

Country	Percent 2023 GDP From Manu-facturing*	2023 Value Added by Manufacturing (USD millions)*	Manufacturing Innovation Program Name	Owner	Year Started	# of Institutes	Est. Total 2023 Annual Program Budget** (USD millions)	Est. 2023 Government Program Base Funding** (USD millions)	% Program Investment per Manu-facturing GDP (USD millions)	Program Investment per Manu-facturing GDP - Indexed to the U.S.
USA	10%	$2,840,447	Manufacturing USA	Government Agencies	2014	18	$540	$160	0.019%	1.0
China	26%	$4,781,179	Manufacturing Innovation Centers	Government of China	2016	33	Unknown	Unknown	N/A	N/A
Germany	19%	$838,894	Fraunhofer Institutes	Fraunhofer Society	1949	76	$3,225	$374	0.375%	19.6

*GDP numbers were sourced from the World Bank and U.N. Stats, in USD current prices. [accessed 17 March 2025]. [28, 29] The U.S. 2023 value was sourced from NIST's Annual Report on the U.S. Manufacturing Economy: 2024. [30]
**2023 expenditure estimates for the Manufacturing USA and Fraunhofer Institutes were derived from their respective Annual Reports. [31, 32] China's MICs-specific program budget and government base funding are unknown.

The U.S. has 10 % of its 2023 national GDP from manufacturing value-added [30], whereas World Bank estimates show Germany's and China's fraction of manufacturing contribution to GDP is 19 % and 26 %, respectively. [28] With respect to the percentage of investment in these countries' specific manufacturing innovation programs, annual reporting data from the U.S. and Germany show that the U.S. invests drastically less in the Manufacturing USA program compared to the Fraunhofer Institutes; Germany invests almost 20 times their national manufacturing GDP into the Fraunhofer Institutes as the United States invests in Manufacturing USA. With respect to the Chinese MICs' investment, budget numbers for their network of 33 known MICs were not publicly available. Some data exists for China's earliest MIC; for example, the National Power Battery MIC reportedly received 400 million USD during its creation [1], but such data for other MICs is largely unknown. Further, this estimate does *not* include the larger investments made for the broader Made in China 2025 initiative that supports infrastructure and other resources that additionally feed the MICs. Reports from the Mercator Institute for China Studies (MERICS) and China's State Council estimate state bank investments will exceed 10 billion Chinese yuan (CNY) (~1.5 billion USD) annually: [22, 33]

> *"Major state-owned banks such as the China Construction Bank, the Industrial and Commercial Bank of China (ICBC) and the China Development Bank (CDB) offer financing. In November 2016, CDB pledged an estimated 300 billion CNY to the implementation of [Made in China 2025] over the next five years. Reportedly, in March 2018, there were more than 1,800 government industrial investment funds with an aggregate size of about three trillion CNY."*

This equates to about 41 billion USD over five years in the form of loans, treasury bonds, leasing, and other investments towards Made in China 2025 implementation, and as much as 413 billion USD in total as of March 2018.

3.2.4. Linkage with Other Central and Regional Government Entities

While Manufacturing USA institutes are encouraged and given the ability to engage with federal agencies beyond their sponsors, national laboratories, and state programs, this is not mandated. Each individual Manufacturing USA institute can seek these collaborations depending on its own topical area alignment with a national, state, or local entity.

Germany's Fraunhofer Institutes collaborate closely with universities in Germany as well as in the U.S., China, and Singapore, with many Fraunhofer Institutes directly integrated into their local universities. The Fraunhofer Institutes have various established forms of collaboration, including high-performance centers and Cybersecurity Training Labs, as well as alignment with other German initiatives like the Excellence Strategy and the German Federal Ministry of Education and Research Campus. [34]

In contrast, China has systematized the linkage of other programs to MICs, allowing the MICs to serve as technology hubs through a coordinated approach at all levels of government and across the entire country.

China's Network Strategy for End-to-end Manufacturing

The Made in China 2025 national policy emphasized the transformation of China's reputation from the home of cheap, manufactured goods to a powerhouse of high-tech innovation, from idea to final product. As mentioned, all levels of government, from central to provincial and local, have a role in this strategy to secure the manufacturing supply chain from end to end, and reach the national goal of 80% production by domestic supply chains in key industries. The *Manufacturing Innovation Center Construction Project Implementation Guide (2016-2020)* provides guidance on the broad, coordinated implementation of the program using central and local government resources along with private support. Various sections indicated that the "expectations" of the central government are generally followed by all parties as much as possible.

As mentioned, China has been heavily investing both in industry sectors where it already leads to maintain its competitive edge, as well as in emerging industry sectors where it seeks to lead. A key industry encompasses biopharmaceutical and advanced medical device products. For instance, although Boston, Massachusetts in the U.S. maintains its rank as the world's leading hub for the health sciences, some of China's most populous cities are rapidly gaining ground. [35] Shanghai is the site of the first hospital intended to be a part of a comprehensive network of national medical centers that boast not only state-of-the-art facilities and extensive talent-recruitment programs but also strong connections to the city's universities and research institutions. China's largest research institute, the Chinese Academy of Sciences (CAS), holds half of the country's leading international partnerships in the biological sciences. [36] Hence, one of the biopharmaceutical MICs, the National High-Performance Medical Device Innovation

Center, expects to tap into Shanghai's talent pool as well as its financial markets, encouraging foreign investment in wealth management joint ventures in the city. [37]

"State Key Laboratories" are another example of China's coordination in creating technology hubs. A lead university or private sector laboratory is granted the State Key Laboratory designation with the Ministry of Science and Technology (MOST) approval and funding for a particular topic. In 2019, State Key Laboratories employed over 50 000 permanent staff and have seen funding increase from 221 million USD to 993 million USD per year. [38] It is thought that the State Key Laboratory system is informed by the OECD's "National Innovation System" framework. [39] This framework is intended to facilitate the transition of science and technology from the country's basic to applied research. While most State Key Laboratories are managed by China, increasingly more of these labs are run by private enterprises to strengthen industry-relevant R&D and connections between industry and academia. Further, a State Key Laboratory can then be transformed into or otherwise support a MIC.

The network of entities supporting a MIC draws upon local and regional strengths and can connect across the country to leverage satellite locations with other capabilities. The inset box (below) on Wuhan city in China's Hubei province shows how one such area has emerged as a model city for manufacturing innovation in IT. [40]

Another example of China's strategy of leveraging regional and local capabilities is the technological hub-and-spoke implementation of their New Energy Vehicles and Advanced IT target industry sectors, where existing strengths of different cities and provinces unite in solving science and technology challenges for the common good. In the second inset box (below), the cities of Beijing and Hefei highlight how R&D and manufacturing capabilities in the areas of energy storage, internet of things (IoT) [41], and common mechanical components [42] have led to China's domination of the electric vehicle sector, with another MIC (the National New Energy Storage Innovation Center) recently announced in Guandong province, already home to four other MICs. Chinese enterprises have innovated across the spectrum, from product and process design to business model innovation and customer experience. [43, 44] Several MICs in these cities are poised to maintain China's competitive edge in IoT-connected EVs. [45–47]

Wuhan: the Pilot City for "Made in China 2025"

The city of Wuhan in the Hubei province has the largest cluster of optoelectronics industries in China, with 42 universities and over 60 members of the CAE and CAS. Hence, Wuhan is home to two MICs in the Advanced IT target industry sector designated by the "Made in China 2025" strategy:

- The **National Information Optoelectronics Innovation Center** (established in 2017) focuses on the optoelectronics industry innovation platform, next-generation networks, data center optical interconnects, and 5G as well as core chip technology and advanced package integration.
    - Run by the Wuhan Optics Valley Information Optolelectronics Innovation Center Co., Ltd, this MIC is jointly formed by several domestic companies including the lead Accelink Technologies, which initiated the MIC and has over 130 national projects and more than 100 national and industry standards.
    - This MIC is affiliated with State Key Laboratories such as Wuhan Optoelectronics National Research Center based at Huazhong University of Science and Technology, and represents one of the nation's core "National Research Centers."
- The **National Innovation Institute of Digital Design and Manufacturing** (established in 2018) focuses on digital design, analysis, and manufacturing to build platforms and core industrial software and process equipment for key areas of digital and intelligent manufacturing.
    - Run by the Wuhan Digital Design and Manufacturing Innovation Center Co., Ltd., this MIC has 15 shareholders and registered capital of 140 million CNY (~19 million USD) in 2018.
    - Huazhong University, Tsinghua University, Shanghai Jiaotong University, Zhejiang University, General Research Institute of Mechanical Science, and FAW Group jointly initiated the MIC, which is affiliated with the State Key National Laboratory, the National Engineering Center of Digital Manufacturing Equipment, among others.
    - Satellite network and regional centers include North China for simulation, East China for its automotive industry, South China for intelligent manufacturing production lines/workshops, and West China for its aerospace industry.

Beijing and Hefei: World Leaders in Electric Vehicles

In 2023, nearly 60 % of EV registrations (8.1 million) were in China, and in that same year, China exported over 4 million electric cars, making it the largest auto exporter in the world.

- In Beijing, the **National Power Battery Manufacturing Innovation Center** (established in 2016) focuses on batteries for cars, scooters, full-size buses, and other transportation with the goal to "sustain the battery revolution."
    - Run by China Automotive Battery Research Institute Co., Ltd, this MIC is part of the Beijing Non-Ferrous Metal Research Institute located in the high-tech Haidian District.
    - A pilot plant demonstration factory with stated investments of 890 million CNY (~123 million USD) resides north of Beijing, while another production validation plant with stated investments of 2 billion CNY (~275 million USD) resides in Sichuan, where electronics and aerospace are key industries.
- In Beijing, the **National Innovation Center of Intelligent and Connected Vehicles** (established in 2019) focuses on cross-vehicle, cross-communication terminals, cross-chip modules, cross-security platform interconnection application demonstrations, and technology roadmaps.
    - Run by the China Intelligent and Connected Vehicles (Beijing) Research Institute Co., Ltd., this MIC was jointly initiated by the China Society of Automotive Engineers, China Association of Automobile Manufacturers, and China Industry Innovation Alliance for the Intelligent and Connected Vehicles.
    - Beijing municipal government established the world's first autonomous driving demonstration zone that features vehicle-road-cloud integration, allowing 30+ companies a collaborative space for IoT R&D and the deployment of 800+ self-driving cars for testing.
- In Hefei, the **National Innovation Center for Basic Components of General Machinery** (established in 2023) focuses on common mechanical parts for high-end products to reduce foreign dependency on key core technologies, ensuring security and independent control of the industrial supply chain of major technical equipment.
    - Run by Hefei General Machinery Research Institute Co., Ltd., this MIC settled in Hefei, known as the EV capital of China, as it is home to six car manufacturers and hundreds of upstream and downstream industry chain enterprises, outputting nearly a million EVs in 2023.
    - This MIC leverages local R&D such as the Hefei Institutes of Physical Science operated by the CAS, including research divisions in optics and fine mechanics, intelligent machines, and others.

4. External Analysis of Implementation of Chinese Plans

The Made in China 2025 and 14th Five-Year Plan are reaching their end dates of 2025. Analysts have been identifying areas to watch for both success measures and for content of future five-year plans. Note, as mentioned above, that some of this analysis includes the Manufacturing Innovation Centers as part of a larger strategy as it can be difficult to separate individual program metrics with publicly available information.

Specifically, analysts cited below are seeking insights on adoption rates for Chinese-made advanced components, conflicting funding priorities, and China's ability to gain market share in high-end manufacturing technologies.

4.1. Adoption Rates for Advanced Technologies

Similar to the U.S., China is also struggling with the pace of adoption of advanced manufacturing technologies by the overall national base of manufacturers. As highlighted by the SCSP's *National Action Plan for United States Leadership in Advanced Manufacturing*: [5]

> "*Like the United States, the PRC has experienced challenges in encouraging domestic manufacturing firms to adopt advanced manufacturing technologies; according to PRC state-affiliated sources, only 37 percent of manufacturers in China have reached a basic level of digitization and industrial intelligence, while only 4 percent of Chinese manufacturers have attained leading-edge capabilities*."

A 2025 IMD study [48] makes a similar observation:

> "*While China has made substantial strides in robotics, industrial automation, and aerospace, the country remains highly dependent on imported high-end machine tools to meet the demand for advanced technology and specialized equipment.*"

They continue to note that such limitations will hamper self-sufficiency efforts.

Comparatively, in the United States, the Small Business Administration reported in a 2023 survey [49] that only 32.4 % of small- and medium-sized manufacturers (SMMs) reported using cloud-based technology and a 2015 McKinsey Global Institute estimated that full adoption of digital technologies will require upgrading about 40 to 50 % of current U.S. manufacturing assets. [50]

4.2. Conflicting Funding Priorities

According to a report by the University of California Institute on Global Conflict and Cooperation and MERICS [51], China is focusing on the full "innovation chain," in addition to innovation institutes. This focus involves attention to locating research institutes near manufacturing firms and creating organizations that unite scientific and commercial resources. This is one of the central roles emphasized for the Manufacturing Innovation Centers in the 14th Five-Year Plan. [4] However, the report also finds that these efforts are extremely costly and difficult to manage, leaving their success in question. On one hand, within a well-resourced system, there will be wins and losses, and the wins could be impactful enough to buffer any

losses. Within that balance, innovation leadership in particular sectors can still significantly increase. At the same time, too much control may hinder the flexibility needed to respond to the market. This leaves open the final determination of whether the U.S. can remain dominant.

Further, the New York Times reports that China has been shifting economic focus from housing and real estate to the manufacturing sector. [52] The report questions how that move will play out both for the current oversupply of Chinese factories and current export policy:

> *"China has already built enough solar panel factories to supply the entire world's needs. It has built enough auto factories to make every car sold in China, Europe and the United States. And by the end of 2024, China will have build [sic] in just five years as many petrochemical factories as all of those now running in Europe, plus Japan and South Korea."*

Their analysis indicates much of this growth will be focused on developing countries as Chinese domestic spending has decreased and other developed nations are looking to decrease imports.

A recent Congressional Research Service report similarly identifies Chinese overcapacity as an issue in the high-end manufactured goods markets. [53]

The world external to China is noticing and reacting: [25]

> "*The policy's focus on self-reliance and elevating China to a more competitive position in the global technology market has triggered a backlash from other countries, most notably the United States, which in 2018 launched a trade war against China in the form of increased tariffs, sanctions and more recently, an artificial intelligence (AI) chip ban. Such restrictions could make it difficult for China to meet its [Made in China 2025] targets in areas of relative weakness, including semiconductors, high-precision machinery and new materials, says Marina Zhang, an innovation researcher who specializes in China at the University of Technology Sydney, Australia. Some researchers also worry that China's focus on areas that align with the government's priorities might stifle creativity among scientists.*"

4.3. High-end Manufacturing Gap

China is signaling its desire to close the high-end manufacturing gap (Fig. 5). The SCSP's *National Action Plan for United States Leadership in Advanced Manufacturing* [5] explores this gap in more detail. Specifically, it quotes a Center for Economic Policy Research Report: [54]

> "*From 1995-2020, China's global share of advanced industry output increased from 3 percent to 25 percent.*' SCSP surmises China has '*reemphasized advanced manufacturing…as the critical engine of economic growth, aiming to promote 'digital transformation' across the industrial sector*."

As the New York Times [52] reported:

> *"Net lending to industrial companies skyrocketed from $63 billion in the first nine months of 2019 to $680 billion in the first nine months of 2023. That money has gone partly toward building a semiconductor industry that may allow China to wean itself from imports and bypass American export controls, as well as toward categories like electric car manufacturing and shipbuilding."*

While not yet dominant internationally, Bloomberg expects the Chinese semiconductor market to be competitive through 2030. [55] EVs are another 'watch this space' category for China. The first, and several of the initial manufacturing innovation centers, contributed to the growth of their EV market and the goal to develop and manufacture all components in-house. [25] China's institutes also contribute to research on alternatives to fossil fuels, especially in photovoltaic cells.

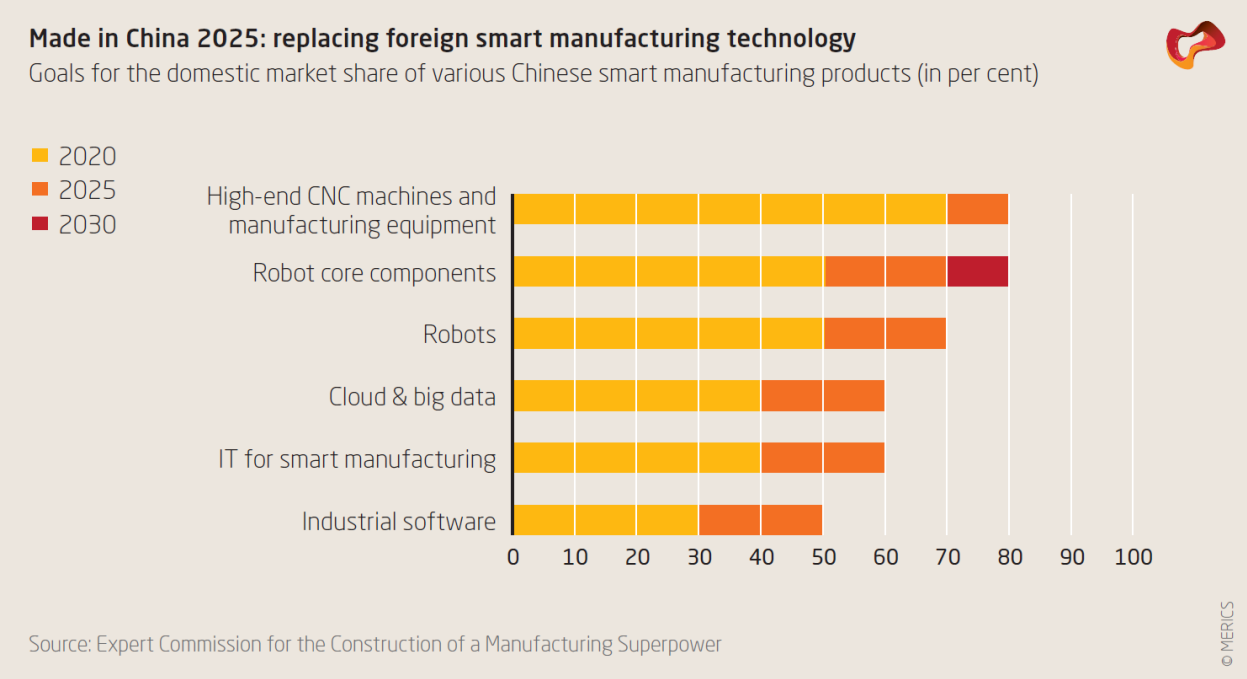

Figure 5: Made in China 2025: Replacing Foreign Smart Manufacturing Technology

Source: Jost Wubbeke, Mirjam Meissner, Max J. Zenglein, Jaqueline Ives, and Bjorn Conrad, "Made in China 2025: The making of a high-tech superpower and consequences for industrial companies." *MERICS.* (December 2016). [17]

Excerpt: "Made in China 2025: Global Ambitions Built on Local Protections." *U.S. Chamber of Commerce.* [18]

5. Innovation Leadership

Both Manufacturing USA institutes and the Chinese Manufacturing Innovation Centers exist to drive innovation by catalyzing R&D and driving the outputs into production. Tracking the structure and function of the MICs can bolster ongoing U.S. efforts to evaluate China's progress in critical technologies and the Made in China 2025 initiative. [56]

These main tasks for the MICs, as described in the *Manufacturing Innovation Center Construction Project Implementation Guide (2016-2020)* [20], differ from Manufacturing USA structures:

- Strengthen the protection and utilization of intellectual property rights,
- Strengthen the guiding and guaranteeing of standards, and
- Serve the public for entrepreneurship and innovation.

It is notable that the Chinese 14th Five-Year plan specifically mentions their innovation centers as foci for regional economic development. In the U.S., similar thinking drove recent legislation creating the Economic Development Administration (EDA) Tech Hubs and National Science Foundation (NSF) Engines programs, among others. [57]

China also has a standards development plan. [58] This strategy, released in 2021, has implications for aligning international standards. Technical standards that enable smart manufacturing were also outlined as a "main priority" in the Made in China 2025 initiative, as it is through standards that information flows within and across organizations and supply chains are governed. [59] While not directly related to the Manufacturing Innovation Centers, the plan could have serious implications for NIST-related organizations.

China views manufacturing as foundational to its strength, from both economic and defense perspectives. It is striving to become independent of foreign sources for critical technology and invests massively in developing manufacturing technology to capitalize on transitioning innovations from around the world into products made in China.

As a result, China currently maintains a significant trade surplus as a percentage of global GDP, has increased its manufacturing investment growth rate by 5.8 % in the past 8 years, and its export market share is growing in key areas such as electric vehicles, electrical equipment, chemicals, and machine tools. [55, 60] According to a recent Congressional Research Service report, the 2024 U.S. trade deficit with China increased by about 16 billion USD over 2023 levels. [53]

The U.S. remains the world leader in innovation and invention, but the ability to transition these innovations and inventions into the domestic industrial base and high-value commercial products is lagging behind China. This is due in part to inadequate development of manufacturing technology and capacity, and insufficient incentives for companies to manufacture in the U.S. in our market-driven economy. China has chosen to invest substantially in the development of advanced manufacturing technology and supporting infrastructure to further national interests in technical domination.

6. Appendices

A. Table and Map of China's Manufacturing Innovation Centers

B. Economic and R&D Trends in the Top 3 Manufacturing Nations

C. Additional Resources

D. List of Acronyms

Appendix A. China's Manufacturing Innovation Centers

Note that there may be some variation in the naming of the MICs, which may not reflect official English translations. Additionally, each MIC may align with more than one target industry sector. Therefore, a "principal" industry sector is designated here.

A.1. Table of Manufacturing Innovation Centers

No.	Manufacturing Innovation Center	Year	Province	City	Principal Industry Sector
1	National Power Battery Manufacturing Innovation Center	2016	Beijing	Beijing	New energy vehicles
2	National Institute of Additive Manufacturing	2016	Shaanxi	Xi'an	Advanced materials
3	National Information Optoelectronics Innovation Center	2017	Hubei	Wuhan	Advanced IT
4	National Printing and Flexible Display Innovation Center	2018	Guangdong	Guangzhou	Advanced materials
5	National Integrated Circuit and Intelligent Sensor Innovation Center	2018	Shanghai	Shanghai	Advanced electrical equipment
6	National Robot Innovation Center	2018	Liaoning, Heilongjiang	Shenyang, Harbin	Advanced machine tools and robotics
7	National Innovation Institute of Digital Design and Manufacturing	2018	Hubei	Wuhan	Advanced IT
8	Lightweight Materials Technology Institute	2018	Beijing	Beijing	Advanced materials
9	Smart Sensor Innovation Center	2018	Shanghai	Shanghai	Aviation and spaceflight equipment
10	National Advanced Rail Transportation Equipment Innovation Center	2019	Hunan	Zhuzhou	Advanced rail transit equipment

11	National Intelligent and Connected Vehicle Innovation Center	2019	Beijing	Beijing	New energy vehicles
12	National Agriculture Machine Innovation Center	2019	Henan	Luoyang	Agricultural technology
13	National Advanced Functional Fiber Innovation Center	2019	Jiangsu	Suzhou	Advanced materials
14	National Rare Earth Functional Materials Innovation Center	2020	Jiangxi & Inner Mongolia	Ganzhou	Advanced materials
15	National Integrated Circuit Characteristic Process and Packaging Test Innovation Center	2020	Jiangsu	Wuxi	Advanced electrical equipment
16	National High Performance Medical Device Innovation Center	2020	Guangdong	Shenzhen	Biopharmaceuticals & advanced medical device products
17	National Advanced Printing & Dyeing Technology Innovation Center	2020	Shandong	Tai'an	Advanced materials
18	Silicon-Based Heterogenous Integration National Innovation Center	2021	Chongqing	Chongqing	Advanced electrical equipment
19	National 5G Medium & High Frequency Device Innovation Center	2021	Guangdong	Shenzhen	Advanced IT
20	National Glass New Material Innovation Center	2021	Anhui	Bengbu	Advanced materials
21	National High-end Intelligent Household Appliances Innovation Center	2021	Shandong	Qingdao	Advanced electrical equipment
22	National Intelligent Voice Innovation Center	2021	Anhui	Hefei	Advanced IT

23	National Modern Chinese Medicine Innovation Center	2021	Tianjin	Tianjin	Biopharmaceuticals & advanced medical device products
24	National Ultra HD Video Innovation Center	2022	Sichuan, Guandong	Chengdu	Advanced IT
25	National Virtual Reality Innovation Center	2022	Jiangxi	Nanchang	Advanced IT
26	National Graphene Innovation Center	2022	Zhejiang	Ningbo	Advanced materials
27	National High Performance Coating Material Innovation Center	2023	Jiangsu	Nanjing	Advanced materials
28	National Innovation Center for Basic Components of General Machinery	2023	Anhui	Hefei	Maritime equipment and high-tech vessels
29	National New Energy Storage Innovation Center	2023	Guangdong	Guangzhou	New energy vehicles
30	National Molecular Drug Innovation Center	2024	Guangdong	Shenzhen	Biopharmaceuticals & advanced medical device products
31	National Humanoid Robotics Innovation Center	2024	Shanghai	Shanghai	Advanced machine tools and robotics
32	National Micro Nano Manufacturing Innovation Center	2024	Shandong	Yantai	Advanced materials
33	National and Local co-Build Embodied AI Robot Innovation Center	2024	Beijing	Beijing	Advanced machine tools and robotics

A.2. Map of Manufacturing Innovation Centers

Target Industry Sectors	MIC HQ Count
Adv. IT	6
Adv. Rail Transit Equipment	1
Adv. Materials	10
New Energy Vehicles	3
Biopharm. & Adv. Medical Device Products	3
Adv. Electrical Equipment	5
Adv. Machine Tools and Robotics	3
Agricultural Technology	1
Maritime Equipment and High Tech Vessels	1
Aviation and Spaceflight Equipment	0

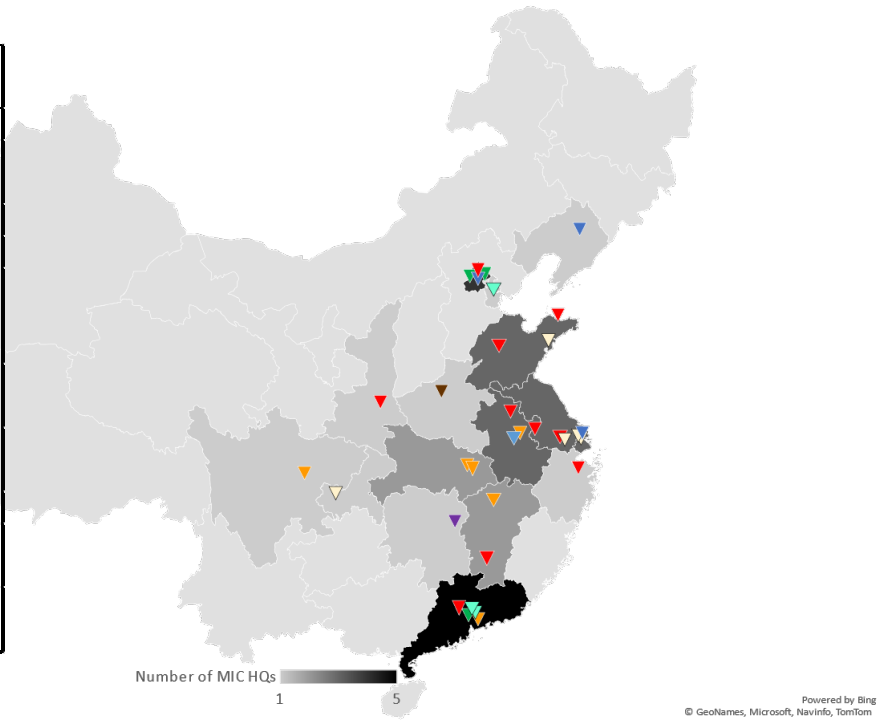

Figure 6: Map of Chinese Manufacturing Innovation Center Headquarters (HQs)

Appendix B. Economic and R&D Trends in the Top 3 Manufacturing Nations

The last decade has seen significant growth in China in both manufacturing infrastructure and research and development capabilities. The increase in these proficiencies, leveraged by the size of China's available workforce, has played a significant role in China's rapid rise in manufacturing as a global power. China's expanding footprint in this sector, and the upheaval caused by this shift in market power, has pushed most of the world's major manufacturing nations to carefully reassess their positions within this changing landscape.

Several indicators are available to assess China's expansion in manufacturing. One gauge of manufacturing health is a country's value added by economic activity in manufacturing. According to the U.N. National Accounts [29], China displaced the United States to become the largest manufacturing nation somewhere between 2009 and 2010 (Fig. 7). Germany, on the other hand, has shown nominal growth in manufacturing value added in the past 20 years. Since that time, China's manufacturing output has continued to increase with an annual growth rate of 4.2 % in 2023 compared to the U.S.'s annual growth of 0.3 %, widening the gap between the two nations. This accounts for China holding nearly 30 % of the global manufacturing value added in 2023, with the U.S. and Germany holding 22.7 % and 10.5 %, respectively.

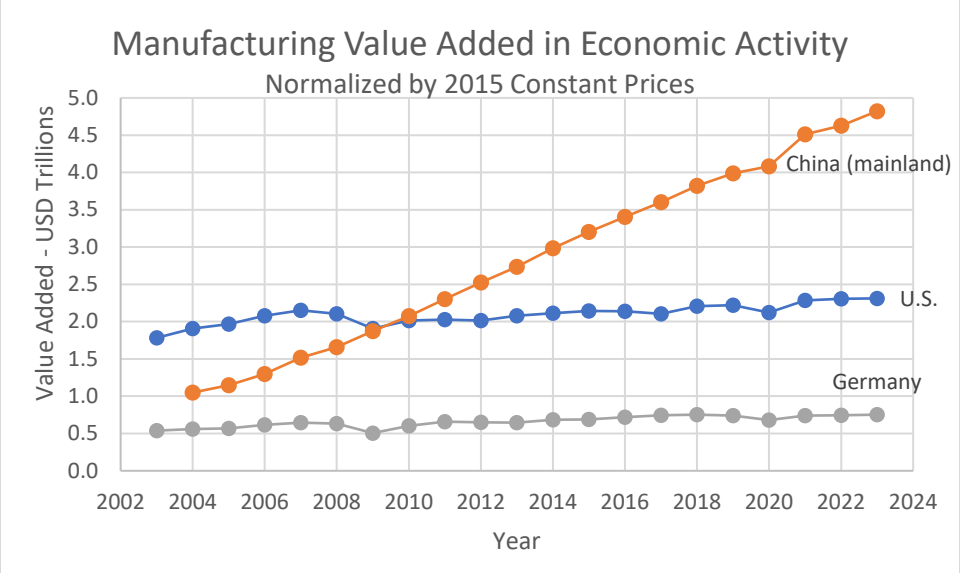

Figure 7: Manufacturing Value Added in Economic Activity (in Constant Prices) Over Time for the U.S., Germany, and China

Source: U.N. Stats National Accounts Database, Value added by Economic Activity in Manufacturing at constant prices, 2015 Prices – U.S. dollars Extracted: 20 March 2025. [29]

U.N.'s 2015 constant price benchmarking (Fig. 7) demonstrates that, over the last 10 years, all three countries have had stable trends in value added in manufacturing, with the U.S. and Germany exhibiting very limited growth while China manifests significant sustained, linear growth.

Sustaining leadership in manufacturing requires a commitment toward the future, with investments in workforce education and emerging technology development. While recent years have seen a slowing of the annual growth rate of GDP and manufacturing R&D investments by these three countries on a percentage basis, both the *growth* and the *rate of growth* of China's total expenditures in manufacturing R&D continue to exceed that of the U.S. (Fig. 8).

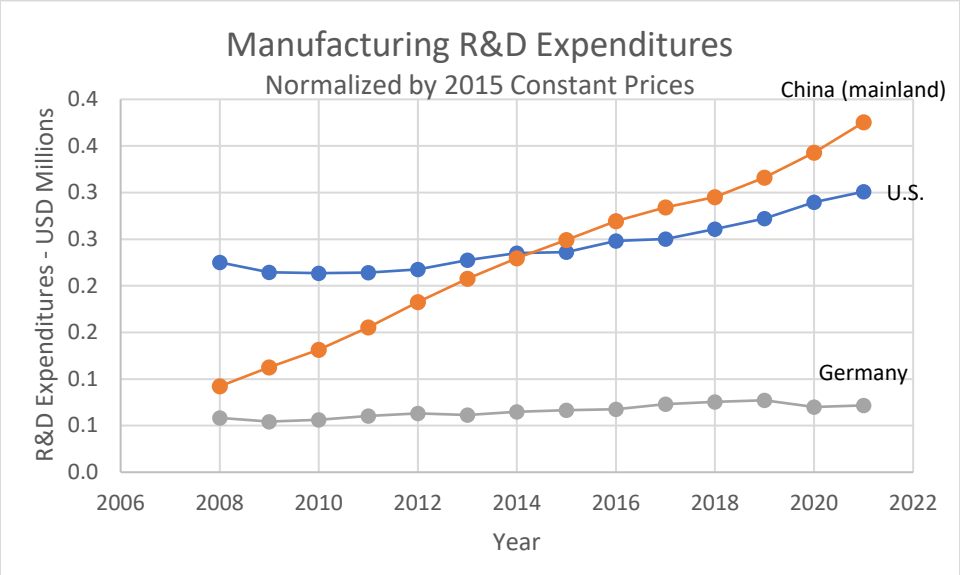

Figure 8: Manufacturing R&D Expenditures (in Constant Prices) Over Time for the U.S., Germany, and China

Source: OECD: Business enterprise R&D expenditure by industry – Purchasing Power Parity (PPP) Dollars in Constant Prices, 2015 U.S. Dollars. Extracted: 20 March 2025. [8]

The long-term health of a country's manufacturing sector extends beyond its immediate production capabilities. Several key indicators suggest that China is cognizant of these requirements and is aligning itself toward a sustained leadership role in manufacturing. In addition to significant economic investments in manufacturing, China has also had substantial year-over-year increases in the research and innovation indicators shown below, although these are imperfect metrics and may not reflect all relevant R&D and technology commercialization indicators.

China has had rapid growth in patent applications normalized per million people (Fig. 9) as well as increases in scientific and technical journal article publications per million (Fig. 10), whereas Germany and the U.S. show signs of slowing down according to these two indicators. The number of R&D researchers per million people (Fig. 11) is steadily increasing in China, showing parallels with the U.S. and Germany in rate of growth. It is worthy of note that when looking at smaller countries by population, such as Germany, their ability to compete in R&D and manufacturing rivals their more populated counterparts, as evident in these graphs, which take into account each country's relative population in a given year. Additionally, although Germany

produces significantly less than China and the U.S., its engineering and quality are highly regarded. For example, Germany ranked first in the "Made-in-Country Index" compared to the U.S. and China, which ranked 10th and 49th, respectively. [61]

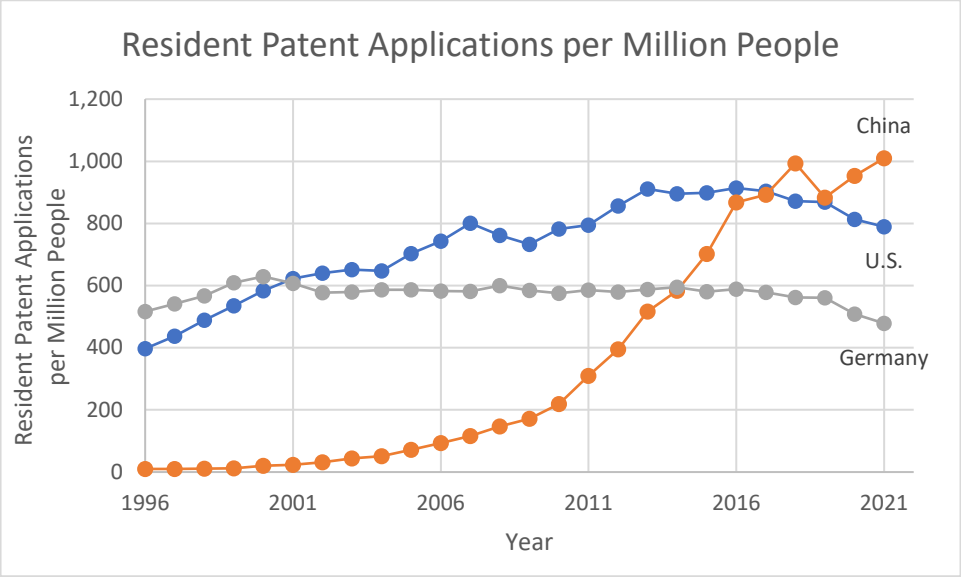

Figure 9: Resident Patent Applications per Million People Over Time for the U.S., Germany, and China

Source: World Bank. 2024. World Development Indicators. [28]

However, when looking at gross numbers, China has exceeded both the U.S. and Germany in all three of these metrics. Compared to the U.S. in the most recent year of complete World Bank data, China has applied for more than five times as many patents (in 2021), has over one and a half times as many people in R&D (in 2020), and has published nearly two times as many scientific journal articles (in 2022). [28]

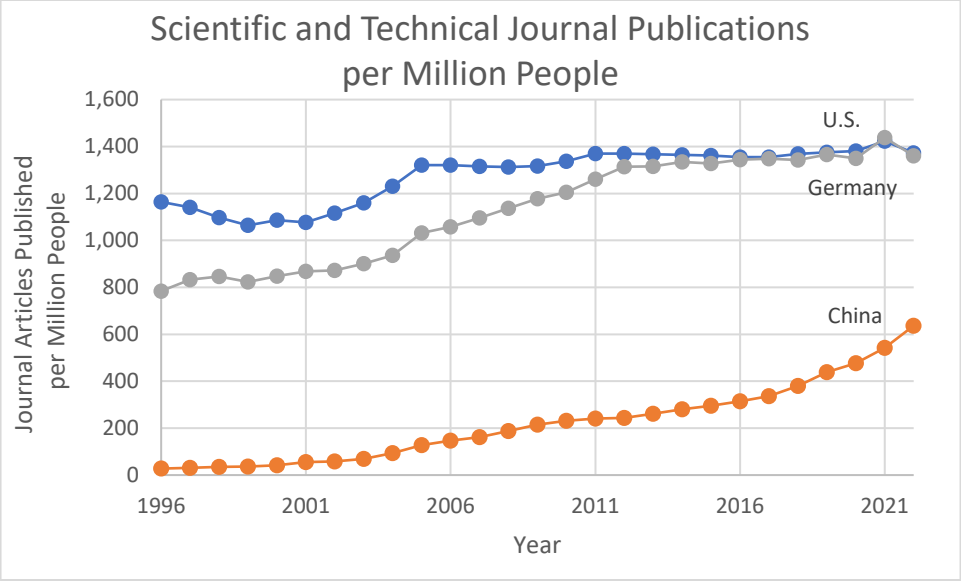

Figure 10: Journal Articles per Million People Over Time for the U.S., Germany, and China

Source: World Bank. 2024. World Development Indicators [28]

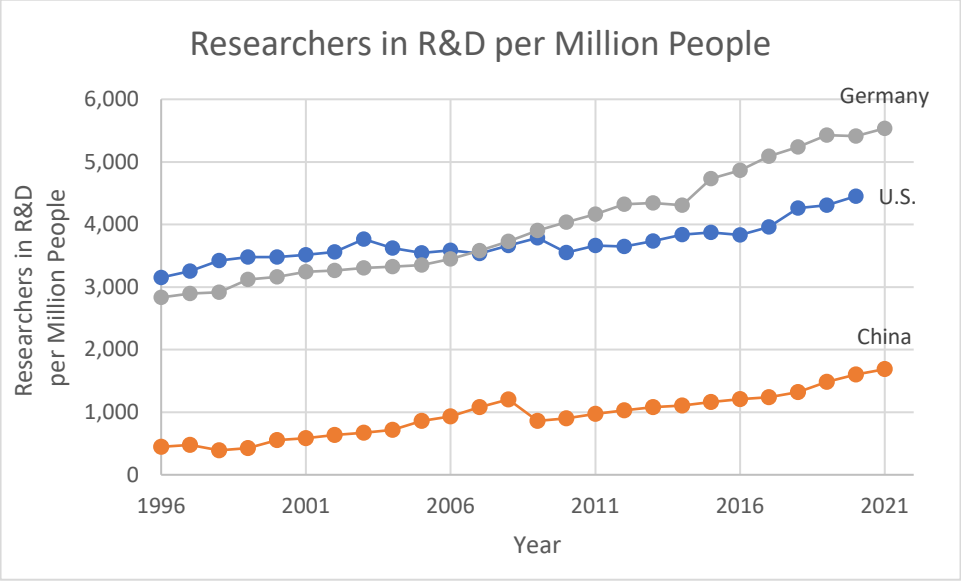

Figure 11: Researchers in R&D per Million People Over Time for the U.S., Germany, and China

Source: World Bank. 2024. World Development Indicators. [28]

Appendix C. Additional Resources

C.1. Congressional Research Service

The following references from the Congressional Research Service provide analysis of manufacturing in the U.S., China, and other nations. These resources can be found at https://crsreports.congress.gov/

- *China's Economy: Current Trends and Issues | Congress.gov | Library of Congress*. February 11, 2025. Karen M. Sutter and Michael D. Sutherland.
- *U.S.-China Trade Relations | Congress.gov | Library of Congress*. February 25, 2025. Karen M. Sutter.
- *Made in China 2025 and Industrial Policies: Issues for Congress | Congress.gov | Library of Congress*. December 12, 2024. Karen M. Sutter.

C.2. Organizational Research Institutes

- Georgetown University, Center for Security and Emerging Technology: CSET Publications
- University of California, Institute on Global Conflict and Cooperation: IGCC
- Mercator Institute for China Studies: MERICS Analysis

Appendix D. List of Acronyms

Adv.	Advanced
AI	Artificial Intelligence
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CDB	China Development Bank
CNY	Chinese Yuan
CSET	Center for Security and Emerging Technology (Georgetown University)
EDA	Economic Development Administration
EV(s)	Electric Vehicle(s)
GDP	Gross Domestic Product
HQ(s)	Headquarter(s)
ICBC	Industrial and Commercial Bank of China
IGCC	Institute on Global Conflict and Cooperation (University of California)
IoT	Internet of Things
IP	Intellectual Property
IT	Information Technology
MERICS	Mercator Institute for China Studies
MIC(s)	China's Manufacturing Innovation Center(s)
MIIT	Ministry of Industry and Information Technology
MOST	Ministry of Science and Technology
NIST	National Institute of Standards and Technology
nm	nanometer
NSF	National Science Foundation
OAM	NIST's Office of Advanced Manufacturing
OECD	Organisation for Economic Co-operation and Development
PRC	People's Republic of China
R&D	Research and Development
SCSP	Special Competitive Studies Project
SMM(s)	Small- and Medium-Sized Manufacturer(s)
S&T	Science & Technology
TCM	Traditional Chinese Medicine
TiVA	Trade in Value Added
U.N.	United Nations
USD	United States Dollar
U.S. or **USA**	United States of America

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