

New Challenges and Directions for Technology Innovation in China: A Review of the 14th Five-Year Plan and an Outlook on the 15th Five-Year Plan

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Abstract: This paper reviews the main achievements of China's science and technology (S&T) development during the 14th Five-Year Plan (2021–2025) and connects them to the priorities set out in the 15th Five-Year Plan (2026–2030). Drawing on official Chinese statistics, reports from the World Intellectual Property Organization (WIPO), and peer-reviewed research, the paper traces a steady rise in research-and-development (R&D) intensity, a first-time entry into the global top ten on innovation rankings, and substantial progress in artificial intelligence, semiconductors, quantum technologies, green energy, biotechnology, aerospace, nuclear fusion, and sixth-generation (6G) telecommunications. It then examines how the 15th Plan translates these gains into a new agenda organized around self-reliance, original innovation, and what Chinese policymakers describe as “new quality productive forces”. The paper also identifies persistent challenges, especially in advanced-node chip manufacturing, demographic and fiscal pressure on R&D, and mounting technology-related trade friction, that will shape the trajectory of innovation in China during the coming five years.

Keywords: China; technology innovation; Five-Year Plan; new quality productive forces; industrial policy; artificial intelligence; semiconductors; innovation ecosystem

1. Introduction

China's Five-Year Plans, produced by the Communist Party of China (CPC) Central Committee and approved by the National People's Congress, have long served as the principal vehicle for aligning scientific research, industrial policy, and macroeconomic planning [1,2]. The 14th Five-Year Plan, covering 2021 to 2025, placed technological self-reliance at the center of national strategy for the first time, in direct response to rising trade and technology tensions with the United States and Europe [3]. The subsequent 15th Five-Year Plan, covering 2026 to 2030, was approved by the National People's Congress in March 2026 and doubled down on that orientation, re-framing it as an effort to cultivate “new quality productive forces” (in Chinese: 新质生产力, *xin zhi sheng chan li*) that blend original scientific discovery, advanced manufacturing, and digital infrastructure [4,5].

Assessing China's technological progress over the past five years is complicated by three factors. First, the bulk of quantitative evidence comes from official Chinese data, which are reliable for aggregate figures such as R&D expenditure and patent filings but less so for frontier capability assessments. Second, Chinese innovation now spans a wide technology stack, from mature industrial sectors such as electric vehicles to speculative areas such as brain–computer interfaces and controlled nuclear fusion. Third, many frontier indicators, citations, leading models, world records, are contested and change quickly. Scholarly literature has highlighted these measurement challenges [6,7]. This paper therefore triangulates Chinese official statistics with independent sources such as the WIPO



Global Innovation Index, the International Institute for Strategic Studies (IISS), the Center for Strategic and International Studies (CSIS), the Information Technology and Innovation Foundation (ITIF), and peer-reviewed journals.

The remainder of the paper is organized as follows. Section 2 describes the research methodology and the theoretical framework that guide the analysis. Section 3 summarizes the headline achievements under the 14th Five-Year Plan, using R&D inputs, patent outputs, and sector-specific breakthroughs. Section 4 lays out the principal targets and priority projects of the 15th Five-Year Plan. Section 5 discusses the frontier developments most closely tied to those priorities, including artificial intelligence and semiconductors, brain–computer interfaces and embodied AI, quantum technologies, nuclear fusion, 6G communications, green technology and new energy, the energy–climate and low-carbon transition, biotechnology, and aerospace. Section 6 examines the main risks and challenges that will condition progress in the coming five years. Section 7 draws out policy and managerial implications, Section 8 discusses limitations and directions for future research, and Section 9 concludes.

This paper distinguishes measured capability from stated ambition wherever possible, and reports both Chinese and non-Chinese evidence on contested indicators [8,9].

2. Research Methodology and Theoretical Framework

This section sets out the evidence base and analytical approach of the study. Section 2.1 describes the integrative literature-review and policy-document methodology through which the empirical material was assembled, and Section 2.2 presents the three theoretical lenses, national innovation systems, techno-industrial policy, and the innovation ecosystem, used to interpret the findings reported in the remainder of the paper.

2.1. Research Methodology

This paper employs an integrative literature-review methodology [10,11] combined with a structured policy-document analysis [12]. An integrative review is well suited to synthesising a fragmented and fast-moving evidence base and to generating new conceptual framings rather than merely aggregating prior findings [10,11], while document analysis offers a systematic procedure for treating policy texts, such as Five-Year Plan outlines and ministry white papers, as primary data whose stated objectives can be coded and compared [12]. Three streams of evidence are triangulated. First, official Chinese policy documents and statistical releases, including the outlines of the 14th and 15th Five-Year Plans, the National Bureau of Statistics (NBS) annual R&D bulletins, and ministry-level white papers, are used to establish stated objectives and headline quantitative indicators. Second, reports from international organisations (WIPO, OECD, World Bank) and policy-research institutions (CSIS, ITIF, IISS, MERICS) are used to benchmark Chinese performance against global peers. Third, peer-reviewed academic articles published between 2020 and 2026 in management, innovation, and economics journals are used to establish theoretical interpretation, identify causal mechanisms, and validate empirical claims. Sources were selected through Web of Science searches using combinations of the keywords “China”, “innovation”, “R&D”, “five-year plan”, “semiconductor”, “artificial intelligence”, “new quality productive forces”, and the names of the specific frontier technologies covered in Section 5. The search focused primarily on publications from 2020 onward in order to capture the post-pandemic policy environment in which the 14th Plan was implemented and the 15th Plan was drafted. Where Chinese-language and English-language sources reported divergent figures, both were retained and reconciled through cross-referencing with at least one independent international source [13,14].

2.2. Theoretical Framework

The analysis is anchored in three complementary theoretical lenses. The first is the national innovation systems (NIS) perspective, which conceptualises innovation as the outcome of interactions among firms, universities, public research institutes, and policy actors within a national institutional context [8,15]. The NIS lens is appropriate for analysing China’s centrally coordinated yet increasingly market-driven innovation system. The second is the techno-industrial policy framework, which interprets state-led targeting of strategic technologies as a purposive intervention to shift industrial trajectories [1,16]. This framework is essential for evaluating the role of Five-Year Plans as instruments of mission-oriented policy. The third is the innovation-ecosystem perspective, which emphasises the interdependent relationships between R&D inputs, knowledge spillovers, and firm capabilities in shaping innovation outcomes [17,18]. Together, these lenses allow the paper to move beyond descriptive policy summary and to interpret the 14th- and 15th-Plan record as a case of evolving institutional, fiscal, and ecosystem-level coordination. The three lenses are operationalised across the empirical sections as follows: Section 3 uses NIS indicators (R&D intensity, basic-research share, patent quality, innovation clusters); Section 4 uses the techno-industrial policy lens to map plan priorities; Section 5 applies the innovation-ecosystem

lens to interpret frontier developments, including the energy–climate transition; and Section 6 examines structural risks that the three frameworks help diagnose.

3. Achievements Under the 14th Five-Year Plan (2021–2025)

This section reviews the principal achievements recorded under the 14th Five-Year Plan along three dimensions. Section 3.1 examines the growth and changing composition of research-and-development inputs; Section 3.2 turns to innovation outputs and China’s evolving position in global innovation rankings; and Section 3.3 surveys sector-specific breakthroughs across semiconductors, artificial intelligence, green energy, quantum science, biotechnology, aerospace, nuclear fusion, and 6G. Read together, they show a system whose progress derives less from any single breakthrough than from the accumulation of advances across a broad technological portfolio.

3.1. R&D Investment and Innovation Inputs

China’s headline R&D statistic is straightforward: total gross expenditure on research and experimental development reached 3.61 trillion yuan (approximately US\$495 billion) in 2024, up 8.3 percent year-on-year, and R&D intensity rose to 2.68 percent of gross domestic product, a tenth of a percentage point higher than the previous year [19]. That intensity now exceeds the European Union average of 2.11 percent and is approaching the 2.73 percent average for member states of the Organisation for Economic Co-operation and Development (OECD) [20]. Cumulative R&D spending over the 14th Five-Year Plan period rose roughly 48 percent above the 13th Plan baseline [21]. This sustained growth trajectory continues a decades-long pattern of rapid R&D acceleration that has narrowed the gap with advanced economies [15,22].

The quality composition of R&D also changed. Basic research spending climbed 10.5 percent in 2024 to 249.7 billion yuan, reaching 6.91 percent of total R&D expenditure, well above the 6.09 percent recorded in 2021 [19,23]. While still short of the 8 percent target articulated at the start of the 14th Plan, the trajectory has been consistently upward, reflecting stronger allocations to the Natural Science Foundation of China and a broader network of national laboratories. Scholars have noted, however, that translating basic research funding into frontier breakthroughs requires complementary institutional reforms, including stronger peer-review norms and longer evaluation horizons [6,9]. Firm-level evidence from Chinese high-tech enterprises also shows that R&D investment significantly boosts green radical innovation when enabled by artificial intelligence, underscoring the increasing complementarity between R&D spending and AI diffusion [18]. Table 1 reports the annual series of R&D inputs for 2020–2024, and Figure 1 plots the growth of total R&D expenditure and R&D intensity over the same period.

Table 1. China’s R&D Inputs, 2020–2024.

Year	Total R&D (Trillion Yuan)	R&D Intensity (% of GDP)	Basic Research (Billion Yuan)	Basic Share (%)
2020	2.44	2.40	146.7	6.01
2021	2.80	2.43	169.6	6.09
2022	3.09	2.54	195.1	6.32
2023	3.33	2.58	226.0	6.77
2024	3.61	2.68	249.7	6.91

Source: compiled by the author from data in Refs. [19,23].

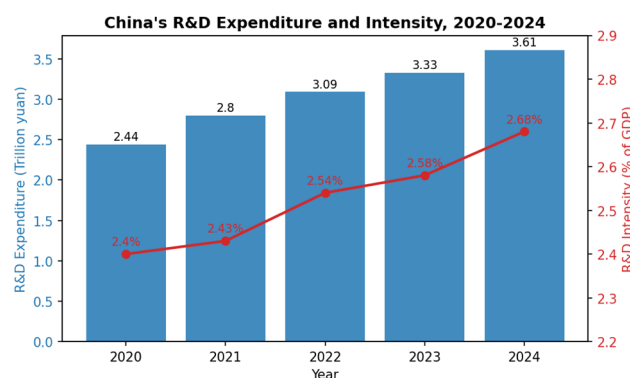


Figure 1. Growth of China’s R&D expenditure and intensity, 2020–2024. Source: author’s own chart, drawn from data in Ref. [19].

3.2. Innovation Outputs and Global Positioning

On the output side, China filed about 1.8 million patent applications in 2024, close to half of the global total, and remained the top filer under the Patent Cooperation Treaty [24]. The country also climbed into the top ten of WIPO's Global Innovation Index (GII) for the first time in 2025, moving from 12th in 2022 and 11th in 2024 to 10th place, making China the only upper-middle-income economy in the top thirty [25,26]. Critical assessments caution, however, that patent counts alone can overstate innovative capacity, and that citation-weighted and forward-referenced metrics yield a more nuanced picture [27,28]. Innovation outputs, capturing knowledge and technology outputs and creative outputs, ranked fifth globally, while innovation inputs ranked 19th, signaling that China converts inputs into measurable innovation efficiently, at least by the indicators used in the GI.

Scientific publications grew in parallel. China produced about 26 percent of the world's peer-reviewed journal articles in 2024, with publication volume up roughly 14 percent year-on-year, consolidating its position as the largest single-country source of scientific output [25]. These figures should be read with caution: volume does not equal frontier leadership, and high-impact citation share remains concentrated in the United States and Europe in many fields. Nonetheless, the trend in citation-weighted share has also narrowed [29]. Recent bibliometric analyses confirm that China has overtaken the United States in its share of articles published in high-quality natural- and health-science journals, though concentration remains in applied rather than foundational research [7,15].

Beyond aggregate counts, the composition of China's innovation clusters has also shifted. In the 2025 GI, four Chinese clusters, Shenzhen–Hong Kong–Guangzhou, Beijing, Shanghai–Suzhou, and Nanjing, now rank in the global top ten by science-and-technology concentration, compared with only two in 2020 [25]. This geographic deepening is consistent with broader efforts to build regional innovation hubs, including the Greater Bay Area, the Yangtze River Delta integration strategy, and the Beijing–Tianjin–Hebei coordinated development plan. Together these clusters account for a disproportionate share of Chinese R&D spending, university funding, and unicorn formation. Empirical analysis of hundreds of Chinese firms has shown that innovation ecosystems shape technological trajectory transitions and significantly affect innovation performance of latecomer firms in such clusters [17,30].

3.3. Sectoral Breakthroughs

Progress was uneven across sectors but pronounced in several areas highlighted by the 14th Five-Year Plan. In semiconductors, Semiconductor Manufacturing International Corporation (SMIC) successfully produced HiSilicon's Kirin 9000s at its 7-nanometer (N + 2) node using deep-ultraviolet (DUV) lithography, despite export controls that block access to extreme-ultraviolet (EUV) tools [31]. This chip powered Huawei's Mate 60 Pro smartphone in 2023 and, according to subsequent teardowns, a 5-nanometer variant appeared in 2024 products. Self-sufficiency targets of 70 percent by 2025 were not achieved, but the roughly 50 percent attained at mature nodes is a significant change from the pre-2020 baseline [32]. These outcomes illustrate the complex dynamics of export controls and their ambiguous impact on the targeted country's innovation pace, as analysed in the emerging literature on semiconductor geopolitics [33,34].

In artificial intelligence, Chinese open-weight large language models have become a major global benchmark. Alibaba's Qwen series and the Hangzhou-based start-up DeepSeek have each achieved performance comparable to leading U.S. closed-source systems at reportedly lower training cost. DeepSeek's V3, released in late 2024, was claimed to have been trained for about US\$6 million using roughly 2000 Nvidia H800 GPUs, and its R1 reasoning model released in January 2025 briefly became the top-rated free application on the U.S. Apple App Store [35,36]. Empirical usage data from OpenRouter indicate that the combined global share of open-weight Chinese models rose from about 1 percent in late 2024 to nearly 30 percent by mid-2025 [37]. This rapid rise of open-weight models from China has been identified as a structural shift in the global AI landscape that may complicate U.S.-led compute governance strategies [38–40].

Green-energy manufacturing reached unprecedented scale. China produced roughly 80 percent of the world's solar photovoltaic modules and 70 percent of electric vehicles (EVs) in 2024, while domestic new-energy vehicle (NEV) market penetration rose from 6.3 percent in 2020 to 48 percent in 2024 [41,42]. Figure 2 plots the rise in NEV market penetration alongside China's share of global PV module production over 2020–2024. BYD alone delivered 4.27 million vehicles in 2024, capturing 34 percent of the domestic EV market. Battery manufacturing capacity exceeded 2500 gigawatt-hours, more than double global demand, and battery exports reached approximately US\$61 billion [41]. The scale and speed of this expansion reflect both targeted industrial policy and substantial learning-by-doing effects that have been difficult for other economies to replicate [43,44].

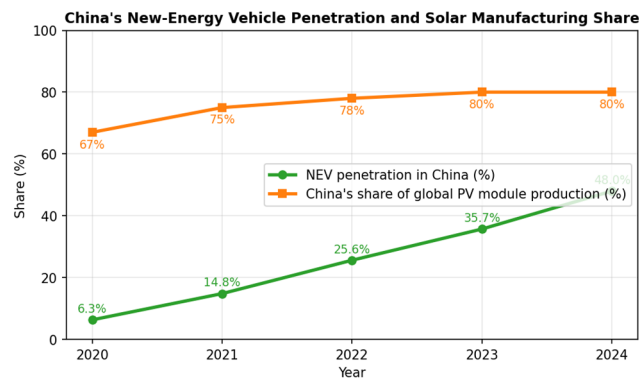


Figure 2. NEV market penetration in China and share of global PV module production, 2020–2024. Source: author’s own chart, drawn from data in Ref. [41].

In quantum science, the University of Science and Technology of China (USTC) advanced both the photonic Jiuzhang platform and the superconducting Zuchongzhi platform. Zuchongzhi 3.0, unveiled in March 2025, featured 105 qubits and was reported to achieve a speed advantage of approximately six orders of magnitude over Google’s SYC-67/SYC-70 random-circuit-sampling experiments published in 2024 [45,46]. Complementary infrastructure, including the Micius quantum-communication satellite, the Beijing–Shanghai backbone, and China Telecom’s Tianyan cloud platform, gave China the world’s largest quantum-secured network [47].

Biotechnology also accelerated. In 2024 the National Medical Products Administration (NMPA) approved 46 Class 1 innovative drugs, including 39 domestic products, a record high [48]. According to a Reuters report citing Vision Lifesciences, Chinese biotech firms accounted for nearly 90 percent of global antibody-drug conjugate (ADC) licensing activity in its 2026 outlook [49]. Cell and gene therapies, especially CAR-T, continued to advance, with more than 300 registered clinical trials and Chinese CAR-T treatment costs substantially below U.S. prices [50]. This trajectory has been documented as a structural transformation of China’s pharmaceutical innovation system, anchored in regulatory modernisation and deeper integration with global clinical networks [51].

In aerospace, the Tiangong space station completed normal-phase operations; in November 2025 the Shenzhou-20 crew set a 204-day national endurance record [52]. China also performed record numbers of orbital launches in 2024 and 2025, and commercial operators such as LandSpace, iSpace, and Space Pioneer began flight tests of reusable rockets. Chang’e-6 returned the first samples from the lunar far side in mid-2024, and Chang’e-7 is scheduled to attempt a water-ice reconnaissance landing near Shackleton Crater in 2026, with a crewed lunar landing targeted for 2030 [53].

Nuclear fusion, long treated as a basic-research field, delivered visible engineering milestones. In January 2025, the Experimental Advanced Superconducting Tokamak (EAST), operated by the Hefei Institute of Plasma Physics, sustained high-confinement plasma for 1066 s, more than doubling its own 2023 record of 403 s [54,55]. Later experiments demonstrated stable operation in a so-called “density-free regime”, relaxing a long-standing constraint on tokamak performance. These results feed directly into the design of the China Fusion Engineering Test Reactor (CFETR) and the Burning Plasma Experimental Superconducting Tokamak (BEST).

In 6G telecommunications, the Ministry of Industry and Information Technology announced in November 2025 that the first phase of 6G technical trials had been completed, producing more than 300 key technology advances. China held 40.3 percent of global 6G-related patents as of mid-2025 and is coordinating field testbeds at Purple Mountain Laboratories, where cell-free massive-MIMO demonstrations have achieved capacity and spectrum-efficiency gains of roughly tenfold over 5G [56,57]. Sustainable-growth analyses of Chinese telecom operators highlight how digital-transformation and platform competition dynamics reshape operators’ investment incentives in next-generation wireless infrastructure [58].

Taken together, these sectoral developments show that the 14th Five-Year Plan period was characterized less by a single dramatic breakthrough than by an accumulation of incremental advances across a broad portfolio. In areas where policy support, domestic demand, and manufacturing capacity aligned, batteries, solar, EVs, commercial drones, and certain AI applications, China consolidated global leadership. In areas that require bespoke capital equipment, tight global supply chains, or decades of tacit engineering knowledge, advanced-node logic, lithography, jet engines, and certain biopharmaceutical modalities, progress was real but the gap with global frontiers did not close uniformly. This pattern sets the stage for the 15th Plan, whose central question is whether the Chinese system can sustain output scale while also deepening original innovation in the harder-to-reach areas.

4. Priorities and Targets of the 15th Five-Year Plan (2026–2030)

The CPC Central Committee issued its formal recommendations for the 15th Five-Year Plan in October 2025, and the final Outline was approved in March 2026 [4,59]. Relative to the 14th Plan, the new document places even more explicit weight on science and technology, treating innovation as the organizing concept rather than an enabling input. This planning cycle represents the latest iteration of what scholars describe as China’s evolving techno-industrial policy paradigm [1,2]. Four strands are especially prominent, and Table 2 summarises how the headline priorities in each domain shifted between the two plans.

First, the Plan calls for “decisive breakthroughs” in core technologies regarded as strategic. The list explicitly includes integrated circuits (covering advanced-node manufacturing, EDA software, and equipment), industrial machine tools, high-end scientific instruments, basic software, advanced materials, and biomanufacturing [60]. A parallel list of 109 major engineering projects singles out green hydrogen, new-type batteries, controlled nuclear fusion, embodied AI, and commercial spaceflight as national flagship efforts [61]. Such mission-oriented programmes echo longstanding debates on the effectiveness of state-led technology targeting and on the conditions under which directed innovation outperforms market-led discovery [16,62].

Second, the Plan broadens the use of the “new quality productive forces” framework first introduced in 2023. The framework reads as a theoretical bridge between basic research and industrial policy, arguing that productivity gains now derive from combinations of original scientific discovery, advanced digital infrastructure, and skilled human capital rather than from capital deepening alone [63]. Under this banner, brain–computer interfaces, quantum computing, and fusion energy are explicitly named as future-oriented productive forces that warrant dedicated fiscal and regulatory support. The framework has been interpreted both as an extension of Marxist productive-forces theory and as a reformulation of endogenous growth theory adapted to Chinese political-economy conditions [62,64]. Related scholarship on human-centric Industry 5.0 further emphasises the role of integrating human capabilities with advanced automation as a distinct source of productivity and innovation in the next industrial cycle [65].

Third, the Plan promotes “coordinated development of education, science and technology, and talent”. This signals larger allocations to basic research, further expansion of the national laboratory system, and stricter evaluation metrics for universities tied to research contribution rather than publication count alone [66]. It also aims to deepen the 2035 vision of modernising the education system, raising gross tertiary enrolment, and doubling the number of doctoral graduates in STEM fields relative to 2020. The concrete institutional expression of this priority came in April 2026, when the Ministry of Education revised its catalogue of undergraduate majors and, for the first time since the 1980s, added a thirteenth disciplinary category, Interdisciplinary Studies, alongside four newly created majors in embodied intelligence, brain–computer science and technology, engineering internet, and deep-Earth science and engineering [67]. This revision is designed to align talent cultivation with the frontier fields prioritised in the Plan and to institutionalise the cross-disciplinary training that emerging fields such as brain–computer interfaces and embodied AI increasingly require.

Fourth, the Plan accelerates the Digital China initiative. Priorities include the national computing power network, large-model infrastructure, data-circulation rules, and an “AI Plus” programme intended to embed AI into manufacturing, agriculture, public services, and household consumption [4]. In contrast to earlier plans, digitalisation is no longer treated as a distinct sector but as cross-cutting infrastructure akin to the electrical grid. The conceptual foundations of this shift, where Industry 4.0 and its emerging enabling technologies reorganise manufacturing, services, and data infrastructure, have been widely reviewed in the information-systems literature [68,69].

Table 2. Selected Priorities: 14th vs. 15th Five-Year Plan.

Domain	14th Plan (2021–2025)	15th Plan (2026–2030)
R&D intensity	Raise to >2.7% of GDP; basic research share >8%	Steady growth; larger share to basic research and national labs
Semiconductors	70% self-sufficiency target; focus on mature nodes	Advanced logic, EDA, lithography, HBM as decisive breakthrough targets
Artificial intelligence	Open-source models; AI application pilots	“AI Plus” initiative; high-end AI chips; embodied AI flagship
Energy & climate	Mass-market EVs, solar, storage; “dual carbon” commitments	Green hydrogen, next-gen batteries, fusion engineering flagship
Space & aerospace	Tiangong permanent crewing; Chang’e 5/6 returns	Crewed lunar landing by 2030; commercial space ecosystem
Quantum & 6G	Zuchongzhi/Jiuzhang records; 6G trial phase 1	Industrial quantum computing; 6G commercialisation by 2030

Source: author’s compilation from Refs. [4,5,60,63].

5. Connecting Plan Targets to Frontier Developments

This section connects the priority targets of the 15th Five-Year Plan to the specific frontier developments now visible in each domain. The subsections proceed from artificial intelligence and semiconductors (Section 5.1) through brain–computer interfaces and embodied AI (Section 5.2), quantum technologies (Section 5.3), nuclear fusion (Section 5.4), 6G telecommunications (Section 5.5), green technology and new energy (Section 5.6), the energy–climate and low-carbon transition (Section 5.7), biotechnology and biomanufacturing (Section 5.8), and aerospace and commercial space (Section 5.9). In each case the aim is to distinguish measured capability from stated ambition and to identify where plan targets are matched by observable engineering or commercial milestones.

5.1. Artificial Intelligence and Semiconductors

The 15th Plan’s twin emphasis on advanced semiconductors and artificial intelligence reflects the tight coupling between model capability and compute availability. After U.S. export controls were tightened in October 2022 and expanded in October 2023 and 2024, Chinese AI developers accelerated algorithmic innovations aimed at reducing compute demand. DeepSeek-V3 and DeepSeek-R1 exemplify this pattern, using mixture-of-experts architectures, chain-of-thought reinforcement learning, and careful communication-efficient training to reach frontier performance on roughly one-tenth the GPU-hours of comparable U.S. systems [35,70]. These results do not eliminate the Chinese chip gap, but they reduce its economic importance. Scholars have argued that such algorithmic substitution effects shift the strategic equilibrium in AI competition by partially decoupling capability gains from hardware frontiers [38,39].

On the hardware side, the 15th Plan’s flagship engineering projects call for domestic advanced logic, high-bandwidth memory (HBM), and lithography. Huawei’s roadmap indicates that the Ascend 950DT is scheduled to become available in the fourth quarter of 2026, while the Ascend 960 is scheduled for the fourth quarter of 2027, with planned improvements in memory bandwidth and chip interconnect capabilities [71]. Domestic lithography equipment made progress, with the Shanghai Micro Electronics Equipment (SMEE) SSA/800 class DUV scanner entering pilot production; EUV remains the binding constraint and is an explicit priority for basic-research funding.

5.2. Brain–Computer Interfaces and Embodied AI

Brain–computer interfaces (BCIs) and embodied AI exemplify the 15th Plan’s ambition to convert frontier science into commercial industries on a compressed timeline. In August 2025, seven ministries jointly issued the Implementation Opinions on Promoting the Innovative Development of the Brain–Computer Interface Industry, which combine industrial planning, medical regulation, and research oversight in a single framework and set out seventeen specific measures spanning ultra-low-power implantable chips, improved electrode materials, real-time neural decoding, and the substitution of domestic components for Western neural processors and high-precision signal chips [72,73]. The roadmap targets a transition of interfaces from testing to clinical use by 2027 and the establishment of a full commercial industry by 2030, and brain–computer interfaces were subsequently named a future industry for priority development in the 2026 government work report [74].

Clinical and commercial progress has been rapid. Semi-invasive, high-channel-count systems have been implanted in patients at leading Chinese hospitals, including a 128-channel flexible wireless interface at Peking University First Hospital [75], while the Shanghai start-up NeuroXess, in a first in-human study published in *Science Advances*, demonstrated real-time decoding of Mandarin speech from cortical signals, a task complicated by the tonal, logographic structure of the language, at a median accuracy of about 71 percent across the full set of 394 Mandarin syllables [76]. In March 2026 a second firm, Neuracle, received regulatory approval for an implantable BCI, and construction began on a dedicated manufacturing facility in Nanchang. As with photovoltaics and electric vehicles, China’s comparative advantage lies less in originating the underlying science than in translating it rapidly into clinical practice and scaled production, a pattern that several analysts expect to prove influential in the BCI field.

5.3. Quantum Technologies

The 15th Plan elevates quantum technology from a research priority to an industrial imperative, calling for commercial deployment pathways alongside continued record-setting [77]. Observed milestones align with this direction. In October 2025, the Hanyuan-1 neutral-atom system began its first commercial deployment. China Telecom’s Tianyan platform, a superconducting quantum-computing cloud service that provides remote access to domestic processors, including an 880-qubit computing cluster and, from October 2025, the commercially available 105-qubit Zuchongzhi 3.0, has recorded more than 37 million visits and over two million computing

tasks from users in more than 60 countries; it is a genuine quantum-computing service rather than a branded classical product [45,78]. Quantum-key-distribution (QKD) networks are being extended from government and finance into power-grid control and inter-provincial backhaul, giving industrial operators early exposure to post-quantum security practice [45]. The commercialization of quantum communication infrastructure positions China as an early mover in applied quantum technologies, even as foundational quantum-computing advantages remain contested in the research literature [79].

5.4. Nuclear Fusion

Fusion is highlighted in the 15th Plan as one of the strategic frontier technologies under the “new quality productive forces” rubric, and the experimental pathway is advancing faster than many Western observers expected. EAST’s 1066-s shot in January 2025 demonstrated that steady-state high-confinement operation is physically attainable, while newer density-free-regime results suggest the Greenwald density limit can be circumvented under certain scenarios [55]. Construction of the Burning Plasma Experimental Superconducting Tokamak (BEST) in Hefei and detailed design of the CFETR are under way, with BEST first-plasma targeted for 2027. If realized, BEST would make China the second country after the ITER consortium to operate a burning-plasma-class experimental device. Fusion research is increasingly described in the literature as a decisive long-term test of state capacity for complex, decades-horizon science missions [80].

5.5. Sixth-Generation Telecommunications

Standard-setting for 6G is still provisional, 3GPP Release 20/21 specifications are under discussion, but China’s industrial base is positioning for early deployment. Purple Mountain Laboratories demonstrated cell-free massive-MIMO testbeds with roughly tenfold gains in coverage and spectrum efficiency over 5G, and a Hong Kong–Beijing team reported ultra-wideband photonic transmission at more than 100 gigabits per second anywhere between 0.5 and 115 gigahertz [56,81]. Commercial rollout, targeted for around 2030, will likely combine non-terrestrial networks, AI-native air interfaces, and integrated sensing and communication. The 15th Plan’s emphasis on the national computing-power network complements 6G by providing the edge-compute substrate that ultra-low-latency applications require. Academic roadmaps converge on a common set of enabling technologies, cell-free massive MIMO, reconfigurable intelligent surfaces, terahertz and visible-light bands, integrated sensing and communication, and AI-native air interfaces, as the features expected to distinguish 6G from 5G [82,83]. China’s IMT-2030 (6G) Promotion Group, established in 2019 to coordinate research across operators, equipment vendors, and universities, has aligned much of the domestic programme with these directions, publishing a consolidated vision and candidate-technology roadmap in 2021 [84], and Chinese institutions have filed a large share of early 6G-related patents [57]. The principal uncertainty is less technical feasibility than standardisation: because the economic returns to 6G accrue disproportionately to holders of standard-essential patents and to those who shape 3GPP specifications, the eventual payoff from China’s testbeds will depend on how far its technical choices are adopted in the international standard rather than on demonstration performance alone [85,86].

5.6. Green Technology and New Energy

Whereas the 14th Plan achieved manufacturing dominance in mature technologies, solar PV modules, lithium-ion batteries, and EVs, the 15th Plan reorients green-tech R&D toward next-generation chemistries and fuels. Sodium-ion and solid-state batteries appear as industrialisation projects; green-hydrogen electrolyser manufacturing is scheduled for further scale-up; and fusion is positioned as the long-term baseload option [61]. Over-capacity in some segments, particularly mid-efficiency solar modules, has already caused price pressure and a projected 19 percent drop in 2025 solar-export value, even as volume rose [41]. The 15th Plan response is to move up the value chain rather than simply add capacity. This shift from capacity to value-added reflects broader concerns about overcapacity and the diminishing returns of pure scale-led strategies in clean-energy industries [44,87]. Parallel work on digital-triad concepts for sustainable manufacturing systems argues that lifecycle information integration is a precondition for turning green manufacturing capacity into durable productivity gains [88].

5.7. Energy, Climate, and the Low-Carbon Transition

Energy and climate policy is one of the clearest points of both continuity and evolution between the two plans. Under the 14th Plan, China pursued binding targets to cut energy intensity and carbon intensity per unit of GDP and reaffirmed its “dual carbon” commitments to peak carbon dioxide emissions before 2030 and reach carbon neutrality before 2060 [89]. The most consequential institutional shift now under way is the transition from

the long-standing “dual control” of energy consumption, capping both total energy use and energy intensity, toward a “dual control of carbon emissions” regime that limits total emissions and emission intensity directly, thereby decoupling economic growth from the absolute energy ceiling that had constrained industrial expansion [90]. This reorientation was signalled in the later years of the 14th Plan and is being operationalised across the 15th Plan period.

The 15th Plan couples this carbon-centred framework with an explicit energy-security logic and a shift from capacity expansion to system-building in the power sector. In July 2026 the State Council issued the Plan for Building a Beautiful China (2026–2030), which organises environmental governance around seven priority tasks, clean air, clean water, healthy soil, ecosystem restoration, active response to climate change, the green and low-carbon transition, and a shift toward sustainable production and consumption, and commits to reaching the carbon-peaking target on schedule while largely establishing green production and lifestyles by 2030 [91,92]. Complementary energy planning reorients investment from simply adding renewable capacity toward building a “new energy system” capable of integrating high shares of variable wind and solar generation, with corresponding attention to grid flexibility, storage, and energy security amid rising geopolitical supply risk [93].

Table 3 summarises the principal shifts in energy- and climate-related objectives between the two plans.

Table 3. Energy and Climate Objectives: 14th vs. 15th Five-Year Plan.

Dimension	14th Plan (2021–2025)	15th Plan (2026–2030)
Control framework	Dual control of energy consumption (total energy use and intensity)	Transition to dual control of carbon emissions (total emissions and intensity)
Headline climate goal	Reaffirm carbon peak before 2030 and neutrality before 2060; cut carbon intensity	Reach carbon peak on schedule; deepen the neutrality pathway; “Beautiful China” by 2035
Energy-system focus	Rapid build-out of renewable generation capacity	Shift from capacity expansion to an integrated “new energy system” with grid flexibility and storage
Governance instruments	Energy-intensity and pollution-reduction targets	Carbon-emission caps, emissions-trading expansion, and non-CO ₂ pollutant control

Source: author’s compilation from Refs. [89–91,93].

5.8. Biotechnology and Biomanufacturing

Biotech is a good example of how the 15th Plan links basic research to industrial deployment. Biomanufacturing, combining synthetic biology, cell-factory design, and bioprocessing, is listed among the decisive-breakthrough priorities, alongside pharmaceuticals. Synthetic biology spending has quadrupled since 2020, and Shanghai’s regional plan targets at least five synthetic-biology platforms and more than ten industry-leading firms by the end of 2025 [94]. The approval record at the NMPA, 46 innovative drugs in 2024, 39 domestic, signals that Chinese regulatory capacity is increasingly compatible with rapid first-in-class development, particularly in ADCs, bispecific antibodies, and cell therapies. The emerging literature documents this trajectory as a structural transformation of China’s pharmaceutical innovation system, driven by coordinated regulatory, financial, and talent reforms [15,51].

5.9. Aerospace and Commercial Space

Aerospace illustrates a longer-term 15th Plan ambition: converting state-led achievement into a commercial ecosystem. By 2025 China conducted a record number of orbital launches, and private launch providers such as LandSpace, iSpace, Space Pioneer, Orienspace, and Galactic Energy were each operating or testing reusable launch vehicles. The Long March 10, an uprated variant planned for crewed lunar missions, is being integrated with a new super-heavy launch complex at Wenchang. Tiangong has been upgraded with additional experiment racks, enabling research in microgravity materials, space medicine, and quantum-in-space demonstrations. The Plan’s call for a “commercial spaceflight” flagship project is meant to institutionalise the market-facing part of the space ecosystem so that it can complement state science missions rather than only supplying them. Scholarly analysis attributes the rapid emergence of China’s commercial space sector to a deliberate alignment of policy, innovation, and market forces, state guidance, procurement, and infrastructure combined with the entry of venture-funded private launch firms, rather than to market liberalisation alone [95]. This state-guided commercialisation model helps explain both the pace of capacity growth and the sector’s continued dependence on public demand, and it remains an open question how far the private segment can operate independently of state contracts.

Deep-space exploration forms the other pillar. Chang’e-6 delivered the first samples from the lunar far side in June 2024, discovering evidence of a distinct mantle composition relative to the near side. Chang’e-7 is scheduled for a 2026 launch aimed at a permanently illuminated peak near Shackleton Crater, carrying a hopping rover to sample shadowed regolith for water ice. Tianwen-2 is under way toward a near-Earth asteroid, and

Tianwen-3 aims to return Martian samples, an objective no other space-faring country has yet attempted. The 2030 crewed lunar landing remains ambitious but credible on the current schedule, with at least two uncrewed precursor missions planned in the interim [53].

6. Challenges and Risks

Several structural risks constrain China's technology trajectory and warrant sober consideration. Notably, in a July 2026 address to the national science and technology conferences and the general assemblies of the Chinese Academy of Sciences and the Chinese Academy of Engineering, President Xi Jinping publicly acknowledged that China's scientific and technological development still faces insufficient capacity for original innovation in some fields, an imbalanced talent-pool structure, low efficiency in the use of science and technology investment, and a persistently low rate of converting research results into practical applications, an official framing that closely tracks the risks discussed below [96]. The first is the advanced-node chip constraint. Even with SMIC's DUV-based 7-nanometer capability, yields at leading-edge nodes remain uneconomic for most applications, and the absence of domestic EUV lithography caps the speed at which 3-nanometer and below can be reached at scale [29,31]. Design-automation (EDA) software and certain materials, such as EUV photoresists and ultra-pure metrology gases, remain dependent on U.S., Dutch, Japanese, and South Korean suppliers. The 15th Plan explicitly names these as bottleneck technologies, but closing the gap will likely take a full plan cycle or longer. Such bottlenecks illustrate the tacit and cumulative nature of semiconductor knowledge production, which resists rapid substitution even under coordinated national effort [33,34].

The second risk is demographic and fiscal. China's working-age population is contracting, while the share of the population aged 65 and above is projected to reach about 18.3 percent by 2030 under the UN's medium-variant projection [97]. Public R&D funding has historically grown faster than GDP, but fiscal pressure from local-government debt and social-security obligations will constrain this margin. The 15th Plan emphasises productivity over input-led growth in part because aggregate labour input is declining. Demographic headwinds have been shown to significantly constrain long-run innovation-led growth unless compensated by productivity gains and human-capital deepening [22,98].

The third risk is external. Technology-related export controls, outbound investment screening, and tariff measures, particularly from the United States and, to a lesser extent, the European Union, have intensified through 2024 and 2025 [5]. China has responded with reciprocal export controls on gallium, germanium, graphite, and rare-earth processing equipment, but these measures raise costs on both sides and do not remove the underlying fragmentation of supply chains. The 15th Plan's stated aim of "high-level opening" coexists uneasily with the parallel emphasis on self-reliance, and the practical balance will depend on bilateral diplomacy as much as on industrial policy. A growing body of scholarship frames these dynamics as the emergence of a fragmented global innovation order with welfare costs on both sides of the divide [99,100]. This fragmentation is increasingly institutional as well as commercial: in July 2026, China hosted the launch in Shanghai of a new intergovernmental body, the World Artificial Intelligence Cooperation Organization, which twenty-nine mostly non-Western states signed and which the United States and the European Union did not join, an indication that technology governance itself may divide into parallel and only partly compatible frameworks [101].

The fourth risk is talent and absorptive capacity. China has enlarged its STEM talent pool rapidly, but the return rate of Chinese-origin researchers from the United States, which has long underwritten talent flows, has fallen since 2021 [66]. The 15th Plan addresses this through enhanced domestic career pipelines and targeted recruitment, but frontier innovation increasingly depends on cross-border circulation, and a decoupled talent system tends to under-perform a connected one. Empirical research on migration and scientific productivity corroborates the view that cross-border researcher circulation is a critical determinant of frontier output [102]. Beyond researcher mobility, the industrial workforce also faces substantial reskilling requirements as Industry 4.0 and AI diffusion reshape demand for technology-specific competencies [103,104].

The fifth risk, often missing from quantitative surveys, concerns the political economy of innovation. China's industrial-policy model relies on sustained coordination between central ministries, provincial governments, state-owned enterprises, and a large private sector in which entrepreneurs and venture capital play an increasing role. Past plans have generated both spectacular successes and durable overcapacity, and the 15th Plan will need to manage this balance more deliberately as capital becomes scarcer. Private-sector confidence, in particular, has been sensitive to regulatory actions in platform technology, education, and property over the past several years. The December 2024 "two-sessions" round of policy statements and the 2025 private-economy promotion law are attempts to restore that confidence, but the durability of the signal will only be tested through the 15th Plan cycle. For foreign investors and partners, the result is a Chinese technology system that is simultaneously more open to

cooperation in pre-competitive research and more closed in sensitive applications than at any point in the past decade. Scholars have characterised this emerging configuration as “party-state capitalism”, under which market actors operate within increasingly explicit political boundaries [105].

The sixth and final risk concerns measurement, specifically, the validity and comparability of the indicators on which any assessment of Chinese innovation depends. Many of the headline statistics discussed in Section 3, such as patent volumes, publication counts, and model-adoption shares, capture the scale of activity more reliably than the quality or frontier significance of the underlying work. A more rigorous assessment therefore requires finer-grained indicators, including citation-weighted measures of research quality, the share of highly cited papers in prioritised fields, start-up formation and venture funding in upstream segments, and capacity-utilisation rates in advanced-node fabrication. These caveats apply symmetrically: they temper optimistic and pessimistic readings of China’s position alike.

7. Policy and Managerial Implications

The synthesis presented above yields a set of implications relevant for policymakers, managers of high-technology firms, and analysts of global innovation. We organise these implications under four headings, mapping each to the analytical lenses developed in Section 2.2.

First, for Chinese policymakers, the evidence supports a continued shift from input-driven to output- and impact-oriented metrics in the science and technology system. While R&D intensity at 2.68 percent of GDP is now broadly comparable to OECD averages, the marginal returns to incremental input increases appear to be diminishing in fields where tacit knowledge, equipment access, and decades-long learning curves dominate. This implies stronger emphasis on basic-research excellence, peer-review reform, and longer evaluation horizons for university and laboratory funding. It also implies strengthening the national technology-transfer system, through proof-of-concept centres and pilot-scale testing platforms, to address the low rate at which research results are converted into applications that the leadership itself has identified as a prominent weakness [96].

Second, for managers of high-technology firms operating in or with China, the 15th Plan’s explicit prioritisation of bottleneck technologies signals both opportunity and risk. Firms positioned in advanced semiconductors, EDA software, scientific instruments, and biomanufacturing are likely to benefit from sustained procurement and subsidy support. However, the political-economy environment also implies tighter coordination obligations with state-owned enterprises and provincial industrial agencies. Strategic decisions on supply-chain localisation, intellectual-property allocation, and joint-venture structures will need to weigh policy alignment against operational flexibility.

Third, for international firms and policy actors outside China, the rapid diffusion of Chinese open-weight AI models, the scale of green-tech manufacturing, and the maturation of frontier infrastructure (quantum, fusion, 6G) imply that strategies premised on an indefinite Chinese lag are unlikely to remain reliable. A more durable response is selective collaboration in pre-competitive science combined with competition in commercial deployment, complemented by domestic industrial-policy investment where national-security or supply-resilience concerns are decisive. The parallel emergence of competing governance institutions, such as the China-hosted World Artificial Intelligence Cooperation Organization, which Western governments have so far declined to join, implies that engagement strategies must also account for a bifurcating landscape of technical standards and rules, and not only for competition among firms and products [101].

Fourth, for the analytics and management research community, the 14th-to-15th Plan transition offers a natural laboratory in which to study the interaction between mission-oriented industrial policy and ecosystem-level innovation dynamics. Future empirical work that integrates firm-level micro-data, plan-target tracking, and outcome-based productivity measures would substantially strengthen the evidence base for evaluating large-scale state-coordinated innovation programmes.

8. Limitations and Future Research

This study has several limitations that should temper interpretation of its findings and that point to productive directions for further research. First, the analysis relies heavily on aggregate, country-level indicators and on official statistics whose definitional boundaries occasionally shift across plan cycles; firm-level and sector-disaggregated data would yield sharper inferences about the productivity gains from specific R&D allocations. Second, several frontier indicators, citation impact, open-source model adoption, patent quality, are still maturing as measurement constructs, and headline figures should be regarded as provisional. Third, the paper covers a wide technology stack at the cost of depth in any single domain; in-depth case studies of individual sectors (for example, advanced lithography, sodium-ion batteries, or antibody-drug conjugates) would complement the present synthesis.

Fourth, the manuscript is restricted to publications dated 2020 or later; the historical antecedents of current policy choices are therefore treated only briefly. Future research could deploy quantitative bibliometric analytics, plan-target attainment scoring, structural-equation modelling of innovation-ecosystem effects, and natural-language analysis of plan documents to test the propositions advanced here on larger and more granular data.

9. Conclusions

This paper makes three contributions to the literature on Chinese technology innovation. Conceptually, it integrates the national innovation systems, techno-industrial policy, and innovation-ecosystem lenses into a unified framework for evaluating Five-Year Plan transitions. Empirically, it consolidates the most recent quantitative evidence on China's R&D inputs, innovation outputs, and frontier-sector breakthroughs into a single, internally consistent picture spanning 2020 to 2026. Practically, it translates these findings into implications for policymakers, managers of technology firms, and analysts tracking global innovation dynamics.

The 14th Five-Year Plan period produced measurable and, in some areas, substantial change in Chinese science and technology, though progress was uneven across sectors. R&D intensity rose to 2.68 percent of GDP; China entered the top ten on WIPO's Global Innovation Index; several open-weight AI models became internationally competitive; the manufacturing base for a number of green technologies reached large world shares; and reported results emerged in quantum computing, fusion physics, aerospace, and biotechnology. These outcomes are documented here from the available evidence rather than endorsed, and the sections above note where indicators are contested or capture scale more than quality. The 15th Five-Year Plan builds on this foundation but shifts the emphasis toward original innovation, industrial deployment of frontier science, and cross-cutting digital infrastructure organised under the "new quality productive forces" banner.

Whether the next five years deliver equivalent progress is an open question. Success depends on resolving three tensions: between self-reliance and international collaboration in advanced semiconductors and talent; between scale and quality in R&D outputs; and between ambitious frontier targets and the fiscal and demographic realities of a slower-growing, older economy. The frontier developments reviewed in Section 5 suggest that the Chinese innovation system has sustained momentum in several priority areas, although the pace and durability of progress vary considerably across domains and some indicators remain difficult to verify independently. The open questions are less about whether these projects will advance at all than about how far and how quickly they will translate into broad productivity and welfare gains, for China and, through trade and collaboration, for other economies.

Further research could usefully focus on three areas. First, firm-level studies of how Chinese companies adapt to compute, design-software, and materials constraints would clarify which bottlenecks are tractable through algorithmic or process innovation and which require parity in capital equipment. Second, comparative analysis of the 15th Plan's 109 major engineering projects against analogous programmes elsewhere, such as the U.S. CHIPS and Science Act, the EU Chips Act, Japan's Rapidus initiative, and South Korea's K-Chips Act, would allow a more measured assessment of global innovation dynamics. Third, systematic tracking of outcome indicators, citation impact, commercial adoption, export quality, and spillover to non-target sectors, will be needed to distinguish genuine productivity gains from the input-driven growth of the past.

The general frame for China's technology landscape in 2026 should be analytical: treat each priority area as a distinct case with its own drivers, constraints, and time horizons; weigh inputs against outcomes; and recognise that the next five-year cycle will test whether scale can be converted into sustained frontier leadership across the full technology stack.

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The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies

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