Seeking Innovation-driven Development: From the 14th to the 15th Five-Year Plan

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Abstract: *During the 14th Five-Year Plan (FYP) period, China's innovation-driven development achieved pivotal transition from scale expansion to the dual enhancement of both quality and efficiency. This transition crystallized into a systematic leapfrogging catch-up model grounded in technological complementarity, centered on paradigm leaps, and safeguarded by ecosystem synergy. Technological complementarity has since deepened across different dimensions, thereby fortifying the foundation for optimizing the allocation of innovation resources. Concurrently, broad-based breakthroughs in emerging technological paradigms, most notably artificial intelligence and quantum information, have yielded tangible progress in fostering disruptive innovation. In parallel, the continuous optimization of the innovation ecosystem, driven by institutional refinement, coordinated engagement among diverse stakeholders, and infrastructure upgrades, has provided sustained structural support. Collectively, these developments have significantly bolstered China's R&D intensity, improved patent quality, and elevated the competitiveness of science and technology clusters. Nonetheless, structural constraints persist, including insufficient autonomy in key core technologies, persistent regional imbalances, incomplete ecosystem coordination, and mounting obstacles to international cooperation. Looking ahead to the 15th FYP period, it is imperative for China to upgrade this systematic model, and by advancing three dimensions in a coordinated manner, China can overcome "chokepoint" bottlenecks, reduce regional disparities, and invigorate innovation dynamics, thereby facilitating a transition from a catch-up phase to frontier-level leadership. Such progress is expected to provide a strong impetus for achieving greater high-level self-reliance and self-strength in science and technology, and cultivating new quality productive forces thereby contributing to the realization of the national goal of "basically achieving socialist modernization" by 2035.*

Keywords: *Innovation-driven development; Disruptive innovation; Technological complementarity; Paradigm shift; Innovation ecosystem*

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1. Introduction

As modern technological revolutions converge with geopolitical realignment, innovation has emerged as a decisive variable of national competitiveness and the principal driver of the new global order. China's 14th Five-Year Plan (2021-2025) marked a decisive turning point in the country's innovation-driven development and signaled a shift from extensive scale expansion toward qualitative upgrading. This period carried the strategic mandate of overcoming structural development bottlenecks and cultivating new, sustainable engines of growth. Beyond achieving leapfrog growth in quantitative indicators such as R&D investment and patent output, China achieved historic advances in optimizing technological structures, fostering disruptive innovation, and strengthening its innovation ecosystem, thereby injecting strong and durable momentum into "high-quality" development.

An examination of the intrinsic logic of innovation-driven development reveals two core dimensions: technological structural transformation and technological growth. Technological structure functions as the central mechanism for the allocation of innovation resources, encompassing paradigm evolution, regional and international technological complementarity, reconfiguration of industrial technology networks, and the mobility of talent factors. Technological growth, by contrast, is primarily reflected in the synergistic enhancement of quality and efficiency, manifested in improved patent quality, the upgrading of science and technology clusters, rising total factor productivity, and breakthroughs in disruptive innovation. Together, these elements—paradigm shifts occurring amid technological complementarity and development driven by ecosystem synergy—define the core landscape of China's innovation-driven progress. From this analytical perspective, optimization of technological structure constitutes the core driver of innovation-led growth, and the combined effects of paradigm shifts and technological complementarity represent a key mechanism through which latecomer economies can achieve technological catch-up. Within this process, disruptive innovation serves as the defining hallmark of paradigm transitions, and the innovation ecosystem provides sustained institutional and organizational support for both complementarity and transformation.

Building on this theoretical framework, this study systematically reviews the transformational characteristics of China's innovation development during the 14th FYP period. At the level of technological structure, China advanced from fragmented dispersion toward coordinated integration. In terms of technological growth, development shifted from factor-driven expansion to efficiency-oriented advancement; and with respect to innovation modes, the trajectory evolved from incremental dominance toward an increasing prevalence of disruptive breakthroughs. By examining representative practices, including regional technological complementarity, the rise of firm-level technological capabilities, and sectoral technological upgrades, this paper reveals the endogenous development model underpinning China's innovation progress, one that is characterized by technological complementarity as the foundation, paradigm shifts as the core, and ecosystem synergy as the safeguard. These findings provide robust theoretical insights and practical guidance for addressing future development bottlenecks and advancing toward greater high-level self-reliance and self-strength in science and technology.

The 15th FYP (2026-2030) represents a critical stage in which China will strive to consolidate its foundations and intensify efforts toward basically realizing "socialist modernization" by

2035. At present, the global development environment is marked by the coexistence of strategic opportunities and escalating risks, alongside growing uncertainty and unpredictability. The patterns of competition and cooperation in science and technology are undergoing profound restructuring as well, and rivalry in key core technologies has intensified. Against this backdrop, we argue that it is imperative to lead efforts to achieve high-quality development through the upgrading of technological structures and to address imbalances and inadequacies in development via innovation-driven strategies. Drawing on the achievements of the 14th FYP and the accumulated experience of the systematic leapfrogging catch-up model, accurately identifying deep-seated constraints and critical challenges and clearly defining breakthrough priorities and implementation pathways for the 15th FYP carries significant theoretical value, practical relevance, and strategic urgency. Such efforts are essential for China to overcome its “chokepoint” technological constraints, foster disruptive innovation, narrow regional innovation disparities, enhance its global innovation discourse power, and build an independent and controllable modern technological system.

2. Innovation Practices and Model Synthesis during the 14th FYP Period

Driven by the profound reconfiguration of the global technological landscape and the imperatives of domestic high-quality development, China’s innovation during the 14th FYP period underwent systemic transformation of its technological architecture coupled with simultaneous improvements in quality and efficiency. These advances coalesced into a systematic leapfrogging catch-up model, with technological complementarity as the foundation, paradigm shifts as the core, and ecosystem synergy as the safeguard. Far from a mere summation of isolated dimensions, this model embodies coherent economic logic by optimizing resource allocation, reconfiguring growth dynamics, and ensuring sustainability through self-reinforcing interactions. It offers a clear pathway for latecomer economies to achieve technological catch-up via systemic innovation and thus underpins China’s shift from scale-driven to quality-led development.

2.1 Technological Complementarity: The Foundation for Resource Allocation

Technological complementarity is rooted in the inherent diversity of technological endowments and innovation trajectories across different actors. At its core, it enhances innovation efficiency by facilitating knowledge exchange and functional specialization and serves as the bedrock for innovation-driven development. By leveraging their comparative advantages through technology transfer, collaborative R&D, and resource sharing, diverse innovation entities at the regional, industrial, and corporate levels can achieve a synergy of strengths. This approach can not only lower innovation costs and mitigates R&D risks but also broaden application scenarios. Ultimately, this synergy may help to build the “critical mass” essential for disruptive breakthroughs, positioning technological complementarity as a vital mechanism for the optimized allocation of innovation resources.

At the regional level, China’s spatial technological relationships achieved a transition from homogeneous competition toward differentiated complementarity that fostered a cross-regional collaborative pattern driven by “technological discovery” (Zheng et al., 2022). In the Yangtze River Delta, Shanghai focuses on foundational research and core technology R&D; Jiangsu emphasizes equipment manufacturing and technological commercialization; Zhejiang concentrates on the digital economy and application-oriented innovation; and Anhui directs its efforts toward quantum information and new energy. Together, these four regions have constructed a complete, integrated cross-regional chain encompassing basic research, technology development, and industrialization. In the Beijing-Tianjin-Hebei Region, this cluster has formed a clear functional division of labor, “R&D in Beijing, commercialization in Tianjin, and manufacturing in Hebei”, that has enabled the high-efficiency flow and optimized allocation of innovation resources. Empirical research demonstrates that this regional complementarity has a significant empowering effect on corporate development as well; approximately 25% of the growth in firms’ domestic value-added (DVA) export ratios can be explained by inter-regional technological complementarity (Zheng & Jin, 2024). From the perspective of developmental balance, China’s regional technological gap has steadily narrowed. In 2023, the average technological complexity index in the eastern region reached 65.89, an 8.3% increase over 2020. Additionally, the index for the central and western regions reached 30.32, a year-on-year increase of 25.6%[1], with a growth rate that significantly outpaced that of the east. Behind this growth differential lies a multi-faceted convergence: the central and western regions have successfully “filled their technological gaps” by leveraging innovation spillovers from the east, upgrading their own industrial bases, and utilizing targeted policy support. A coordinated regional innovation landscape has actively taken shape.

At the industrial level, the pervasive penetration of digital technologies in China has dismantled traditional sectoral boundaries, propelling technological complementarity toward deeper integration. By lowering marginal R&D costs, amplifying knowledge spillovers, and enabling cross-domain collaboration, digital technologies have allowed firms to expand their technological portfolios from niche specialization toward multi-field integration, thereby providing essential support for cross-industry innovation. Between 2015 and 2024, the average number of International Patent Classification (IPC) subclasses covered per patent application among China’s A-share listed companies increased from 2.3 to 4.7. Over the same period, the share of digital-technology-related patents rose from 18.6% to 42.3%, and cross-sectoral digital patent applications grew at an average annual rate of 35.8%, underscoring the accelerating pace of inter-industry technological convergence. Through two-way digital empowerment, industries across China have increasingly integrated their production and innovation networks. By 2023, digitalization rates in manufacturing, services, and agriculture reached 45%, 60%, and 25%, respectively, representing increases of 15, 20, and 10 percentage points relative to 2020[2]. Science-based, scale-intensive, and supplier-dominated industries have leveraged these digital tools to achieve cross-boundary integration as well. This process has not only strengthened productivity and innovative capacity in traditional sectors but has also created fertile ground for cross-disciplinary knowledge fusion, steering China’s innovation ecosystem toward greater openness and collaboration.

At the international level, technological complementarity has evolved from one-way importation

[1] Calculated by the author using regional invention patent data and the technical complexity formula.

[2] Calculated by the author based on regional invention patent data and the classification code documents for digital technology patents from the China National Intellectual Property Administration.

to reciprocal engagement, giving rise to a nuanced landscape of so-called "co-opetition" in which complementarity and competition coexist (Zheng et al., 2022). China has developed comparative advantages in mid-to-low-end manufacturing, digital technology applications, and renewable energy sectors, whereas advanced economies continue to lead in foundational research, high-end semiconductors, and core components. This divergence in technological endowments constitutes the structural foundation for international technology trade and collaborative arrangements. During the 14th FYP period, China established over 70 joint laboratories in partnership with Belt and Road Initiative (BRI) countries, creating diversified platforms for international innovation cooperation[3].

In the biotechnology domain, technology licensing transactions between Chinese firms and their European and American counterparts reached 33 in 2023, more than double the 2019 figure, highlighting a markedly strengthened two-way technology flow[4]. Similarly, in terms of talent mobility and knowledge diffusion, China's position within global innovation networks has continued to strengthen. Its centrality in the global inventor mobility network increased from 42 in 2020 to 49 in 2023, reflecting an average annual growth rate of 5.3%. By 2023, China hosted 180 highly cited scientists in artificial intelligence, semiconductors, and biomedicine, a 63.6% increase from 2020[5], placing it second globally in these fields. Such cross-border flows of talent and knowledge not only accelerate worldwide technological advancement but also promote the international dissemination of disruptive innovation concepts, thereby laying a solid foundation for China's deeper engagement in global innovation governance.

At the firm level, enterprises have solidified their role as the core micro-level actors of technological complementarity and the primary incubators of disruptive innovation during the 14th FYP period. In 2024, Chinese corporate R&D expenditure reached 2,821.16 billion yuan, accounting for 77.7% of total national R&D spending, and the R&D intensity of large-scale high-tech manufacturing enterprises averaged 3.35%. This substantial financial commitment has established a solid foundation for pursuing disruptive breakthroughs[6]. The global R&D investment landscape underscores this ascent. According to the EU Industrial R&D Investment Scoreboard, 678 Chinese firms featured among the world's top 2,500 R&D investors in 2021 (17.9% share). By 2024, China maintained strong representation with 525 firms in the top 2,000 (16.1% share), exhibiting particularly rapid growth in emerging sectors such as electric vehicles, semiconductors, and renewables. The leadership of flagship enterprises has been especially prominent. BYD, a representative in the electric vehicle sector, advanced from 129th in global R&D rankings in 2021 to 37th in 2024, with R&D expenditure amounting to 6.673 billion euros[7].

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[3] Source: China Center for International Science and Technology Exchange (CISTE), "The Belt and Road International Science Organization Alliance now has 78 members," September 23, 2025, https://www.ciste.org.cn/gjkjzz/ydylkjzz/art/2025/art_150d75261e4144d8950bb8dc0f86ec72.html.

[4] Source: Sandra Barbosu, "How Innovative Is China in Biotechnology?" July 30, 2024, https://itif.org/publications/2024/07/30/how-innovative-is-china-in-biotechnology/.

[5] Calculated by the author based on inventor mobility data identified from invention patent data.

[6] Source: National Bureau of Statistics, "Statistical Communiqué on National Science and Technology Expenditures in 2024, " September 29, 2025, https://www.gov.cn/lianbo/bumen/202509/content_7042859.htm.

[7] Source: Grassano et al., "The 2022 EU Industrial R&D Investment Scoreboard," Dec.13, 2022, https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard.

By establishing complementary technological linkages with battery material suppliers in central and western China and automotive component manufacturers in the eastern region, BYD constructed a vertically integrated industrial chain. As a result, its new-energy vehicle production and sales led globally for nine consecutive years through 2023, and in 2025, its pure electric vehicle sales surpassed Tesla for the first time, marking a global leadership shift. Its “Blade Battery” technology exemplifies a quintessential paradigm of disruptive innovation. Likewise, Huawei drew on complementary networks in the Yangtze and Pearl River Deltas to forge open 5G industrial alliances, securing China’s global leadership in 5G standards and deployment. The rise of these enterprises, synergistically interacting with regional technological complementarity and ecosystem dynamics, forms the micro-foundational bedrock of China’s contemporary innovation trajectory.

2.2 Paradigm Shifts: The Core Engine of Innovation-Driven Growth

Paradigm shifts are marked by breakthroughs in disruptive technologies that break entrenched technological path dependencies, reconfigure technological systems and industrial structures, and ultimately reshape growth logic. When marginal returns to innovation decline within an established technological paradigm, disruptive technologies generate new market demand, restructure industrial value chains, and propel economic growth into new long-wave cycles. These shifts are not isolated breakthroughs but evolve across a full chain: foundational research, iterative applications, and industrialization. Disruptive innovation runs throughout this process and serves as the critical inflection point that enables qualitative leaps in innovation-driven development.

Multi-point breakthroughs occur in emerging technological paradigms. During the 14th FYP period, China witnessed the accelerated emergence of new technological paradigms, most notably in artificial intelligence, quantum information, new energy, and biotechnology, and coordinated breakthroughs across multiple fields laying a solid foundation for paradigm shifts. In artificial intelligence, China has built a relatively complete technological system that spans chips, foundational frameworks, and application-layer deployment and that enables large-scale commercialization in areas such as intelligent speech recognition and computer vision. In quantum information, major advances include the preliminary establishment of an integrated space-ground quantum communication network and the successful deployment of thousand-kilometer-scale quantum key distribution, opening pathways toward industrial application. In the new energy sector, Chinese firms have achieved a dominant global position: CATL and BYD together account for more than 60% of the global power battery market, and repeated world-record-setting photovoltaic conversion efficiencies have accelerated the global transition toward green and low-carbon energy systems[8]. In biotechnology, MGI accounts for approximately 7% of the global gene sequencing market in terms of revenue[9], and technological breakthroughs in genetic testing and biopharmaceuticals have provided important support for the Healthy China initiative. Collectively, these advances in emerging technological paradigms have not only driven rapid industrial growth but also reshaped

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[8] Source: 360estorage, “China’s Power Battery Industry Dominates the Global Market: Market Share Surpasses 60% as Production Surges 12-fold in Three Years,” October 27, 2025, https://baijiahao.baidu.com/s?id=1847126555804189092&wfr=spider&for=pc.

[9] Source: Zheng Bingxun, “Seizing the Multi-Billion Dollar Market: Domestic Gene Sequencing Firms Ignite a Competitive ‘Replacement War’,” February 10, 2025, https://finance.sina.com.cn/roll/2025-02-10/doc-ineizenw4006685.shtml.

global competitive dynamics, creating favorable conditions for China's technological catch-up.

Tangible progress is seen in the cultivation of disruptive innovation. The cultivation of disruptive innovation in China has yielded measurable outcomes. Based on assessments of patent differentiation from prior technologies and their influence on subsequent innovation, disruptive patents accounted for 8.3% of China's total invention patents in 2023, an increase of 3.1 percentage points compared to 2020. Although this share remains below that of the United States (12.1%) and Germany (10.5%)[10], the narrowing gap underscores the rapid strengthening of China's disruptive innovation capacity. Leadership effects are particularly evident in several key domains. In semiconductors, Huawei's HiSilicon Kirin 9000S achieved mass production, breaking long-standing foreign monopolies over advanced manufacturing technologies. In artificial intelligence, DeepSeek realized breakthroughs in intelligent reasoning by developing models capable of unified processing of text, code, and visual information, overcoming cold-start constraints through unsupervised reinforcement learning and achieving significantly faster inference speeds than comparable models. In new-energy vehicles, BYD's aforementioned Blade Battery redefined safety standards for power batteries, shifting the technological paradigm from "energy-density prioritization" toward a balanced emphasis on safety and performance and guiding the global trajectory of battery technology development. These disruptive innovations have not only strengthened core competitiveness in related industries but have also driven comprehensive upgrading of China's technological systems.

A deep coupling exists between disruptive innovation and technological complementarity networks. The cultivation of disruptive innovation is deeply embedded within technological complementarity networks. Empirical evidence indicates that improvements in the allocative efficiency of inventor mobility, both inflows and outflows, significantly enhance urban-level disruptive innovation performance. The effect is particularly evident when incoming inventors exhibit strong complementarity with the host city's technological base while maintaining low overlap with the originating city's technological profile. This mechanism operates most effectively within innovation ecosystems characterized by dense collaboration networks and "high-quality" research teams, highlighting the critical enabling role of technological complementarity in driving paradigm shifts.

Innovation clusters function as powerful platforms for technological complementarity and disruptive breakthroughs, demonstrating significant agglomeration effects. In 2023, the proportion of disruptive patents within China's premier innovation clusters—most notably the Yangtze and Pearl River Deltas—markedly surpassed the national average. The World Intellectual Property Organization's *Global Innovation Index 2025* reports that China now hosts 24 of the world's top 100 innovation clusters, ranking first globally, with the Shenzhen-Hong Kong-Guangzhou cluster claiming the top position worldwide[11]. These hubs concentrate approximately 60% of national R&D expenditure, 70% of R&D personnel, and 80% of high-tech enterprises, solidifying their role as the central engines of technological progress. The Shanghai-centered Yangtze River Delta

[10] Calculated by the author based on disruptive patent data identified using existing methods for identifying disruptive technology patents.

[11] Source: WIPO, "Global Innovation Index 2025," https://www.wipo.int/web-publications/global-innovation-index-2025/en/index.html.

integrated circuit cluster exemplifies this dynamism: it encompasses three of the world's top ten wafer foundries, two of the top ten packaging and testing firms, and five emerging domestic integrated device manufacturers (IDMs). In 2022, the cluster's combined revenue from IC design, manufacturing, and packaging/testing reached 723.5 billion yuan, over 60% of the national total, vividly demonstrating the pivotal role of clusters in driving paradigm shifts[12].

2.3 Ecosystem Synergy: The Institutional Safeguard for Innovation

Ecosystem synergy, as a crucial safeguard within the systematic leapfrogging catch-up model, reduces transaction costs, information asymmetries, and inherent uncertainties in innovation activities through multiple pathways, including institutional design, stakeholder coordination, and infrastructure development. By accelerating knowledge spillovers and technological diffusion, it simultaneously serves as a "safety net" and an "accelerator" for high-risk disruptive innovation, thereby constituting a vital safeguard within the systematic leapfrogging catch-up model. At its core, this synergy manifests as a multidimensional integration of institutional, stakeholder, infrastructural, and cultural alignment, thereby delivering the sustainable structural support essential for technological complementarity and paradigm transitions.

Institutional synergy works to optimize innovation incentives. The nationwide rollout of punitive damages for patent infringement, combined with the progressive establishment of cross-regional intellectual property protection mechanisms, has significantly reduced the average resolution period for IP disputes. These reforms effectively protect the legitimate rights and interests of disruptive innovators, thereby invigorating creative momentum across the country. Deep reforms to the scientific evaluation system have also dismantled the entrenched "papers-and-quantity" bias, granting Chinese researchers substantially greater autonomy over human, financial, and material resources as well as technological direction, explicitly encouraging the pursuit of high-risk, high-reward disruptive research. Concurrently, ongoing advancements in factor marketization and the accelerated construction of a unified national market have eliminated regional protectionism and market segmentation, removing institutional barriers to the free flow of innovation factors and significantly enhancing resource allocation efficiency throughout China.

Stakeholder synergy fosters collective innovation impetus. Chinese enterprises have fully consolidated their position as the central actors in innovation, assuming a leading role in tackling chokepoint technologies and commercializing disruptive outcomes. For example, in 2024, Chinese corporate R&D expenditure accounted for 77.7% of the national total[13], and contracts between enterprises and universities/research institutes for technology development, consulting, and services reached 201.07 billion yuan, a 1.9-fold increase from 2020, demonstrating the deepening intensity of university-industry collaboration (Deng, 2026). Mechanisms for industry-academia-research synergy have continued to mature since then, effectively harnessing academia's strengths in fundamental research and industry's market-driven orientation through joint R&D, talent

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[12] Source: Center for Yantze River Delta and Economic Belt Research, "Joining Forces in the Yangtze River Delta to Build a World-Class Integrated Circuit Industry Cluster," April 26, 2024, https://cyrdebr.sass.org.cn/2024/0426/c7499a568926/page.htm.

[13] Source: National Bureau of Statistics, "Statistical Communiqué on National Science and Technology Expenditures in 2024," September 29, 2025, https://www.gov.cn/lianbo/bumen/202509/content_7042859.htm.

mobility, and other channels. As another example, by 2023, collaborative disruptive patents from Chinese university-enterprise partnerships accounted for 38.6% of the national total, an increase of 9.2 percentage points over 2020[14], vividly illustrating the pivotal role of this synergy in nurturing disruptive innovation. Collectively, diverse innovation actors in China have coalesced into an "enterprise-led, university-supported, institute-coordinated" force that ensures seamless integration across the entire innovation chain, from basic research through to full-scale industrialization.

Infrastructural and cultural synergies provide a resilient and mutually reinforcing foundation for innovation-driven development. Comprehensive upgrades to physical and digital infrastructure have established a solid backbone for technological progress. By the end of 2023, China had deployed 3.377 million 5G base stations[15], delivering the high-speed, low-latency connectivity essential for deep digital integration and the emergence of disruptive innovations, and by late 2022, 150 industrial internet platforms of significant sectoral or regional influence had been established, forming a multi-tiered ecosystem that connects over 81 million sets of industrial equipment[16]. As of February 2025, China's national scientific research facility-sharing platform had integrated more than 141,000 large-scale instruments[17], dramatically lowering hardware barriers and enabling small and medium-sized enterprises (SMEs) to pursue disruptive innovation at reduced cost. Concurrently, the technology transaction market expanded sharply, from 2.8 trillion yuan in 2020 to 6.8 trillion yuan in 2024 (Deng, 2026), serving as a vital conduit for the transfer of complementary technologies and the commercialization of disruptive outcomes. Complementing these material advances, sustained efforts to cultivate an innovation-oriented culture have fostered a supportive social environment. The vigorous promotion of the scientist spirit, entrepreneurial spirit, and craftsmanship has contributed to the gradual emergence of a societal ethos that encourages bold exploration while also tolerating failure. Initial fault-tolerant and error-correction mechanisms have both been instituted, effectively alleviating researchers' concerns about engaging in high-risk, high-reward disruptive work. This inclusive and open innovation culture, when integrated with world-class infrastructure, delivers comprehensive support for innovative activities and accelerates the intertwined processes of technological complementarity and paradigm transitions.

In summary, China's innovation trajectory during the 14th FYP period exhibits distinctive stage-specific characteristics and a profound multi-dimensional transformation. In terms of growth dynamics, the country has shifted decisively from factor-driven to efficiency-driven models, with disruptive innovation emerging as the defining hallmark of quality enhancement. Spatially, the landscape has evolved from uneven agglomeration toward coordinated and balanced development, propelled by deepening regional technological complementarity that fosters nationwide synergistic development. With respect to innovation actors, the underlying model has transitioned from single-entity dominance to multi-stakeholder collaboration, with enterprises firmly consolidating their

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[14] Calculated by the author.

[15] Source: Xinhua News Agency, "Total Number of 5G Base Stations in China Reaches 3.377 Million," January 19, 2024, https://www.gov.cn/lianbo/bumen/202401/content_6927123.htm.

[16] Source: CCTV News, "China's Multi-tier Industrial Internet Platform System Preliminarily Established," March 29, 2023, https://www.gov.cn/xinwen/2023-03/29/content_5749133.htm.

[17] Source: Wu Wenqian, "Over 141,000 Sets of Large-scale Scientific Instruments Integrated into National Sharing Platforms," February 26, 2025, https://news.sciencenet.cn/htmlnews/2025/2/539385.shtm.

central role and industry-academia-research synergy achieving marked gains in effectiveness. In the global dimension, the paradigm has moved from one-way technology importation to two-way engagement, substantially elevating China's position and disruptive-innovation influence within international innovation networks. Collectively, these transformations signal that China has entered a new era centered on high-quality development that has laid a robust foundation for realizing even more ambitious innovation breakthroughs during the 15th FYP period.

2.4 Synthesis of China's Innovation Development Model

The transformative achievements of China's innovation during the 14th FYP period are deeply rooted in a systematic leapfrogging catch-up model: technological complementarity as the foundation, paradigm shifts as the core, and ecosystem synergy as the safeguard. Far from a mere summation of isolated dimensions, this model adheres to a coherent economic framework that optimizes resource allocation, reconfigures growth engines, and ensures long-term sustainability to form a nested, self-reinforcing whole. It offers a systematic pathway for latecomer economies to achieve technological catch-up and leapfrogging.

Technological complementarity, as the fundamental basis, applies the logic of comparative advantage to innovation. By leveraging differences in technological endowments, diverse actors can integrate resources across regions, sectors, and borders, thereby offsetting weaknesses while amplifying strengths and building the critical mass needed for disruptive breakthroughs. Within China, this plays out in well-established patterns: R&D concentrated in the eastern regions paired with commercialization and scaling in the central and western regions; digital technologies deeply fused with traditional industries; and close collaboration between leading enterprises and specialized SMEs. These arrangements reduce innovation costs, spread R&D risks, and create fertile ground for breakthroughs. Internationally, two-way flows of technology and talent, both of which are attracting advanced capabilities from abroad and exporting Chinese strengths, help close gaps in foundational research while opening up global markets and resources.

Paradigm shifts serve as the central engine of China's growth as they have fundamentally restructured technological systems and industrial landscapes to propel the Chinese economy into new long-wave cycles. During the 14th FYP period, emerging paradigms in artificial intelligence, quantum information, and other frontier fields steadily supplanted traditional technological paths in China, rapidly giving rise to smart manufacturing, biopharmaceuticals, and a host of other innovative business models. This dynamic vividly captures the essence of "creative destruction" at the core of paradigm shifts: phasing out outdated capacities while simultaneously opening up entirely new arenas for innovation across the Chinese economy. Disruptive innovation stands as the defining hallmark of these transitions in China. It generates not only technological breakthroughs but also deep structural upgrades and fundamental changes in China's development models. Through these shifts, China has transitioned from a phase of technological catch-up to one of strategic parity, and in several frontier domains, global leadership, thus fundamentally reconfiguring the global competitive landscape.

Ecosystem synergy, as the sustainable safeguard, embodies the systematic integration of institutional economics and cluster innovation theory in practice. Through institutional coordination that refines innovation incentives, stakeholder alignment that amplifies performance, infrastructural integration that reduces transaction costs, and cultural reinforcement that cultivates an atmosphere of tolerance and experimentation, ecosystem synergy delivers efficient support for technological complementarity while providing a critical “safety net” for high-risk paradigm shifts. In China, well-developed innovation clusters with mature ecosystems exhibit an R&D input-output ratio and a disruptive patent output density higher than the national average, clear evidence of the powerful amplification effect ecosystem synergy exerts. This multidimensional coordination mechanism ensures the continuous advancement of technological complementarity and paradigm shifts and establishes a stable, resilient, and sustainable environment for innovation-led growth.

These three dimensions form a tightly coupled, two-way cycle of adaptation and dynamic iteration. Technological complementarity aligns with and meets the evolving resource, talent, and capability needs of paradigm shifts, laying the essential groundwork for them to occur. In turn, paradigm shifts pull technological complementarity toward new frontier and incremental domains, driving its progression from basic to advanced levels of integration. Ecosystem synergy continuously adapts to the pace and requirements of this interplay, through institutional innovation, infrastructure enhancement, and other mechanisms, reducing transaction costs, dispersing risks, and stabilizing expectations to enable smooth, interaction between complementarity and paradigm shifts. This model aligns seamlessly with China’s hybrid governance framework in that it is market-driven yet strategically guided by the state, and it closely mirrors the developmental logic of latecomer economies: accumulating comparative advantages through technological complementarity, achieving leapfrog progress via paradigm shifts, and consolidating and sustaining those gains through ecosystem synergy. In this way, disruptive innovation ultimately becomes the mechanism for establishing and maintaining leadership. This systemic innovation development model not only explains China’s achievements during the 14th FYP period but also provides solid theoretical foundations and practical guidance for realizing greater high-level self-reliance and self-strength in science and technology during the 15th FYP period and beyond.

3. Barriers and Critical Challenges for Innovation during the 15th FYP Period

Although China’s innovation system framework took shape during the 14th FYP period, patent statistics, industrial evidence, and international comparisons reveal persistent, deep-seated, and multi-dimensional bottlenecks. As the country advances toward the 15th FYP period with the strategic goal of achieving high-level self-reliance and self-strength in science and technology, these constraints, concentrated in technological supply, innovation quality and efficiency, ecosystem support, and international collaboration, remain interwoven and mutually reinforcing, creating cumulative restrictive effects.

3.1 Deficiencies in Core Technological Autonomy and the Persistent “Chokepoint” Dilemma

High external dependence in core technological domains, combined with entrenched path dependence in key sectors, continues to place China in a predicament characterized by both insufficient source-level innovation and inadequate high-end supply. This structural vulnerability remains the foremost barrier to cultivating disruptive innovation.

In strategic emerging industries, China's patent portfolio exhibits an obvious "periphery-heavy, core-light" pattern, leaving critical technologies vulnerable to external control. While Chinese enterprises have scaled their R&D investments considerably in cutting-edge sectors, a substantial gap persists in their capacity for indigenous innovation regarding fundamental core technologies. Artificial intelligence serves as a representative case. Although China's R&D expenditure constitutes a significant portion of the global total, its patent accumulation in foundational tiers—specifically core algorithms and high-end semiconductors—remains relatively sparse, lagging notably behind leading nations. Currently, the majority of mainstream large-model ecosystems are anchored by foreign high-performance hardware, with underlying architectures largely dependent on overseas open-source frameworks. The semiconductor industry reflects a parallel trajectory. Despite R&D investments that rank among the world's highest, China's patent share in advanced process nodes and essential manufacturing equipment remains disproportionately low. Intellectual property in the high-end chip segment continues to be dominated by international incumbents. Within the highly concentrated market for critical fabrication tools, China's domestic semiconductor industry has yet to achieve autonomous supply capabilities for frontier systems, such as extreme ultraviolet (EUV) lithography. Finally, the biopharmaceutical sector mirrors these structural impediments. While China maintains a formidable global presence in R&D spending, it accounts for a modest proportion of core patents for first-in-class innovative drugs. Patent activity continues to cluster around lower value-added segments, primarily encompassing generic formulations and auxiliary medications. This imbalanced patent structure places Chinese enterprises in a competitive disadvantage in global value chains. They face not only high royalty payments but also frequent patent litigation[18], which significantly undermines their ability to independently develop and secure critical technologies.

Similar gaps persist in frontier domains, particularly quantum technologies. Critical hardware components, such as dilution refrigerators and high-quantum-efficiency photon detectors, remain heavily reliant on imports, and domestic alternatives fall short of the performance and reliability required for advanced quantum computing systems. Significant gaps also remain in key technical indicators, including qubit coherence time, control precision, and progress in foundational areas like quantum error correction, all of which directly hinder the industrialization of quantum technologies in China.

Low investment in basic research represents the most fundamental constraint on original innovation and, by extension, on disruptive breakthroughs. In 2024, China's basic research expenditure accounted for only 6.88%[19] of total R&D spending, well below levels in developed economies, and resulted in chronic shortages of source-level innovation supply. Patent commercialization performance remains weak. According to the EU Industrial R&D Scoreboard (2024), Chinese enterprises achieve a

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[18] Source: Georgakaki et al., "The 2025 EU Industrial R&D Investment Scoreboard," Dec.22 , 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

[19] Source: National Bureau of Statistics (NBS),"Statistical Communiqué on National Science and Technology Expenditures in 2024," September 29, 2025, https://www.gov.cn/lianbo/bumen/202509/content_7042859.htm.

patent conversion rate of approximately 50%, and universities and public research institutes reach only 3.8% and 11.8%, respectively, far below the 20%+ rates typical in advanced economies.[20] As a result, a large volume of basic research outcomes remains trapped in laboratories and fails to translate into disruptive innovations (Ye et al., 2021). The underlying causes of this commercialization bottleneck are threefold. First, low technology readiness levels create a persistent disconnect between laboratory outputs and real industrial needs. Second, the development of pilot-scale and intermediate testing platforms lags significantly, leaving a critical gap between technological prototypes and scalable products. Third, commercialization incentive mechanisms remain underdeveloped: revenue-sharing ratios for researchers are typically low, undermining motivation for technology transfer. Together, these factors introduce structural breakpoints in the innovation chain, creating dual obstacles that impede both the “0-to-1” breakthroughs of original innovation and the “1-to-N” scaling required for industrial application.

3.2 Low Innovation Efficiency and Significant Imbalance between Quantity and Quality

China’s innovation trajectory has long exhibited a structural bias toward quantity over quality. Persistent shortcomings, such as limited technological value in patents, a narrowing scope of innovation activities, and highly concentrated industrial structures, have made deficiencies in quality and efficiency a central constraint on elevating China’s overall innovation competitiveness.

Weak patent quality and limited international competitiveness stand out most clearly. Although China has consistently ranked first or second globally in patent filings, accounting for 32% of worldwide invention patent applications in 2019, the substantive technological impact of these patents remains comparatively low. The average number of forward citations for Chinese patents has trended downward, signaling declining diffusion and influence. At the same time, patent space has become increasingly crowded: by 2019, the average number of applications per International Patent Classification (IPC) category had increased sevenfold compared with 2005 (Boeing et al., 2025). From the perspective of global coverage, 96% of Chinese patents are filed only domestically, and the share of triadic patents (simultaneously filed in Europe, the United States, and Japan) remains negligible, limiting the creation of durable international technological barriers. Citation performance further highlights this gap: in sectors such as photovoltaics, Chinese patent citation rates stand at only 14.9%, far below the levels exceeding 60% achieved by leading firms in Germany, Japan, and the United States (Medvedev et al., 2020). Collectively, these indicators reveal insufficient technological influence and industry recognition for Chinese patents.

The scope of innovation has also continued to narrow, with cross-domain integration weakening and an inward-looking, path-dependent innovation pattern taking hold. Cross-field spillover effects of Chinese patents have steadily declined, as shown by the continuous drop in the average importance of secondary IPC classifications from 1985 to 2019. This trend indicates that technological progress is increasingly reliant on existing intra-field knowledge, with limited engagement in cross-sectoral or interdisciplinary fusion (Boeing et al., 2025). Such structural

[20] Source: Georgakaki et al., “The 2025 EU Industrial R&D Investment Scoreboard,” Dec.22 , 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

closure constrains innovation vitality and hinders the emergence of truly disruptive breakthroughs that typically arise at the intersections of multiple domains, a dynamic that is fundamentally at odds with the integrative nature of digital-economy development.

Industrial innovation remains highly concentrated, resulting in limited risk resilience and relatively low value-added potential. Data from the 2024 and 2025 EU Industrial R&D Investment Scoreboards show that Chinese firms on the list are overwhelmingly clustered in traditional manufacturing sectors, reflecting an apparent lack of diversification. In 2025, firms in ICT hardware manufacturing, automobiles, and construction and materials accounted for 60.3% of all Chinese entries, collectively absorbing 77.4% of total R&D investment. Within this group, ICT hardware alone represented 38.7% of spending, followed by automobiles at 26.3% and construction and materials at 12.4%. In contrast, US firms display a more balanced and high-value-added profile, with 70.9% of R&D concentrated in ICT services and healthcare. EU firms focus primarily on automotive and environment-related Sustainable Development Goal sectors that balance traditional strengths with green transformation, but Japanese firms, though also concentrated in automobiles and electronics, exhibit deeper technological specialization and stronger "hidden champion" traits[21]. This extreme concentration in China's industrial innovation structure weakens the overall ecosystem's resilience: shocks in one or two dominant sectors, whether from technological disruption or market volatility, can quickly propagate across the system. Moreover, insufficient innovation in high-value-added service industries limits upward movement along global value chains, keeping China positioned predominantly in the middle-to-lower tiers of the international division of labor in innovation.

3.3 Deficiencies in the Innovation Ecosystem: Coexisting Institutional and Structural Barriers

A robust innovation ecosystem is essential for supporting technological complementarity and paradigm shifts. Yet in China, the ecosystem continues to face multiple, interconnected obstacles, including fragmented industry-academia-research collaboration, inadequate intellectual property protection, insufficient technology-oriented financing, and misaligned evaluation systems and talent structures, that collectively hinder the full release of innovation potential.

Industry-academia-research collaboration remains loose and poorly integrated, resulting in weak connectivity across the innovation chain. In 2023, cooperative R&D investment between enterprises and universities accounted for only 7% of total corporate R&D expenditure in China, well below the 12% level in the United States. Average technology transfer income per Chinese university is roughly one-fifth that of US institutions, and most collaborations are confined to applied research, with very limited engagement in basic research (Atkinson, 2024; Castro & McLaughlin, 2021). Approximately 70% of research outcomes remain stuck in the laboratory stage, reflecting the absence of critical intermediate commercialization platforms. Data indicate that the density of pilot-scale testing facilities in China is only one-third that of the United States and one-half that of Germany. This underdevelopment of mid-stage testing infrastructure prevents many laboratory achievements from advancing to industrialization due to insufficient technology

[21] Source: Georgakaki et al., "The 2025 EU Industrial R&D Investment Scoreboard," Dec.22 , 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

readiness or prohibitively high production costs[22], leaving the R&D-to-market pipeline incomplete and severely limiting the real-world impact of innovation outputs.

Weaknesses in intellectual property protection and technology finance further undermine ecosystem effectiveness. The average adjudication period for IP infringement cases in China is approximately 18 months, longer than international norms. In 2023, average compensation in IP infringement cases was around 2 million yuan, far below the roughly 5 million USD typical in the United States, and plaintiff success rates stood at 65% compared to 78% in the United States (Atkinson, 2024). In addition, early-stage financing for innovation remains inadequate. Coverage for seed- and start-up-stage enterprises is only 25% in China, significantly lower than 60% in the United States and 45% in Europe, and domestic venture capital allocates just 15% of its funding to early-stage firms, compared to 40% in the United States (Castro & McLaughlin, 2021). This significant "front-end gap" in capital support causes many high-potential start-ups to fail prematurely, severely constraining the emergence and scaling of disruptive innovations.

Structural deficiencies in evaluation systems and talent composition compound these challenges. Research assessment mechanisms in China remain heavily biased toward publication counts and quantitative metrics, particularly in basic research, where evaluation cycles are typically shorter than five years, an approach fundamentally misaligned with the long gestation periods required for truly disruptive innovation. The talent structure also exhibits a bias toward technical specialization over creative and integrative capabilities. Shortages of high-level interdisciplinary talent and globally leading scientific figures are evident: Chinese nationals represent only 12% of the world's top researchers in frontier fields such as artificial intelligence and quantum information[23]. In advanced manufacturing, returnees from overseas account for just 23% of R&D personnel, compared with 35% foreign-born talent in the United States (Atkinson, 2024). These gaps reflect limited internationalization and insufficient talent agglomeration, undermining China's capacity to sustain high-level self-reliance and self-strength in science and technology and long-term innovation leadership.

3.4 Regional Imbalances in Innovation Development and Insufficient Synergy in Technological Complementarity

Persistent regional disparities remain a deep-rooted structural challenge in China's national innovation system. Significant gaps between the eastern coastal regions and the central and western interior continue to exist across innovation capacity, resource allocation, and factor mobility. Institutional and systemic barriers to effective technological complementarity have not been fully removed, constraining the overall efficiency of the national innovation system and limiting the coordinated, nationwide cultivation of disruptive innovation.

Regional innovation gaps remain substantial, with uneven development patterns clearly evident. In 2023, China's eastern region maintained an R&D intensity approximately twice that of the central and western provinces, highlighting a significant regional imbalance in innovation

[22] Source: Georgakaki et al., "The 2025 EU Industrial R&D Investment Scoreboard," Dec.22 , 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

[23] Source: Macro Polo, "The Global AI Talent Tracker 2.0", March 7, 2023, https://archivemacropolo.org/interactive/digital-projects/the-global-ai-talent-tracker/.

investment. This spatial concentration is equally evident in the distribution of high-tech enterprises: the eastern seaboard hosts the overwhelming majority of these firms, while the interior regions account for only a comparatively small share. Indicators of technological complexity reveal a similar divide. While eastern clusters continue to operate along a more advanced technological frontier, the central and western regions face a substantial developmental lag, underscoring persistent structural divergence between China's coastal and inland innovation systems. These differences also extend beyond quantitative metrics and reflect deeper disparities in ecosystem maturity. Eastern regions benefit from dense research platforms, abundant talent pools, and well-developed industrial support systems, whereas the central and western regions face persistent shortfalls in these areas, perpetuating a regional "Matthew effect" in which stronger areas continue to pull further ahead.

Cross-regional factor mobility in China remains costly, and technology transfer efficiency lags. Currently, cross-regional technology transfer constitutes a disproportionately small fraction of the total turnover within China's national technology market. Specifically, the outflow of innovation from the eastern seaboard to the central and western interior remains modest, with a notably thin volume of disruptive or frontier technologies shifting across provincial lines. This bottleneck indicates significant structural impediments to the fluid movement of intellectual property, suggesting that the latent complementarity inherent in China's technological gradients has yet to be fully mobilized. The core reasons for restricted mobility lie in institutional barriers such as local protectionism, market segmentation, and underdeveloped benefit-sharing mechanisms, which continue to hinder the nationwide optimization of innovation resource allocation in China.

The limited absorptive and transformative capacity of China's central and western regions further constrains effective technology diffusion. The innovation ecosystems across China's central and western regions continue to face persistent structural constraints. Compared with the eastern region, these interior provinces contend with a relatively limited pool of high-caliber talent, weaker high-level research infrastructure, and less integrated industrial supply chains. These institutional weaknesses are reflected in several key indicators: the density of R&D personnel remains substantially lower than in the eastern region, while the distribution of national-level research platforms is comparatively limited. Furthermore, the R&D investment intensity of high-tech firms in these regions remains below that of their eastern counterparts, indicating structural impediments that collectively constrain the strengthening of regional innovation capacity. These deficiencies greatly restrict the ability of central and western regions to internalize and build upon transferred technologies. Even when technology transfer occurs, constraints on secondary innovation and industrial scaling prevent effective localization and broader diffusion, thereby deepening and perpetuating regional innovation disparities across China.

3.5 Impediments to International Innovation Cooperation and Rising Challenges in Global Resource Integration

Intensifying global technological competition, coupled with rising technology containment and trade protectionism, has made the external environment for international innovation cooperation increasingly complex and restrictive. China's ability to integrate global innovation resources, exert influence over rule-setting, and achieve effective cross-border technology transfer faces mounting pressures, constituting a major external constraint on innovation-driven development during the 15th FYP period.

Technological containment and trade protectionism have sharply narrowed channels for acquiring core technologies. Several developed economies have pursued “small yard, high fence” strategies, restricting collaboration with China in frontier domains such as semiconductors, artificial intelligence, and quantum information while intensifying export controls on high-end technologies, critical components, and advanced research equipment. As a direct result, China’s imports of high-end semiconductor equipment fell 25% year-on-year in 2023[24], severely limiting access to essential inputs for research and industrialization in strategic sectors. Among the world’s top 2,500 R&D-investing firms, Chinese enterprises continue to lag significantly in cross-border R&D engagement as well. In 2022, cross-border R&D investment represented only 8.3% of total R&D expenditure for Chinese firms, compared to 23.7% for US firms and 18.5% for EU firms. Although this share rose modestly to 8.9% in 2023 and 9.4% in 2024, the corresponding figures for the United States and European Union increased more sharply, reaching 26.8% and 21.3%[25], respectively. This widening disparity highlights the growing difficulty China faces in leveraging global innovation resources to accelerate technological catch-up.

China’s influence in global innovation governance and rule-setting remains limited, with relatively low participation in international standard-setting and institutional frameworks. In 2023, China-led international standards accounted for only 5% of the global total, compared with 25% for the United States and 18% for Germany. In emerging fields such as artificial intelligence and quantum communication, China’s contribution to international standard-setting in 2024 was just 6.8%, far below the 31.4% share of the United States and 24.7% of the European Union (Parker et al., 2022). Structural weaknesses are equally apparent in international intellectual property cooperation. From 2022 to 2025, triadic patents, filed simultaneously in the United States, Europe, and Japan, accounted for only 3.2%-3.8% of Chinese firms’ invention patents, but US firms maintained shares of 28%-31% and EU firms 22%-25%. In 2024, the success rate of Chinese enterprises in international IP disputes stood at 65%, lower than 78% for US firms and 73% for EU firms, underscoring deficiencies in cross-border IP protection and collaboration. Participation in global innovation governance platforms has also been limited: in 2025, Chinese firms accounted for just 12.7% of participants in major international innovation alliances, compared to 41.3% for US firms and 35.6% for EU firms[26]. The persistent shortfall in international discourse power restricts China’s ability to shape global innovation rules in ways that reflect its interests. As a result, international technical standards and IP regimes remain largely dominated by external actors, exposing Chinese enterprises to elevated compliance costs, legal risks, and structural disadvantages.

Chinese enterprises still face significant gaps in integrating global innovation resources, particularly in the strategic placement of overseas R&D networks, the cross-border mobility

[24] Source: US-China Economic and Security Review Commission, “US-China Competition in Emerging Technologies,” 2024, https://www.uscc.gov/sites/default/files/2024-11/Chapter_3--US-China_Competition_in_Emerging_Technologies.pdf.

[25-26] Source: Grassano et al., “The 2022 EU Industrial R&D Investment Scoreboard,” 13 Dec., 2022, https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard; Georgakaki et al., “The 2025 EU Industrial R&D Investment Scoreboard,” 22 Dec., 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

of high-caliber innovation talent, and active participation in international collaborative research programs. According to 2025 data, the number of overseas R&D centers established by leading Chinese firms stands at only 28.3% of the level achieved by US firms and 35.7% of that by EU firms. Moreover, these centers are predominantly concentrated in emerging markets such as Southeast and South Asia, and their presence in global innovation-intensive regions, namely North America and Europe, accounts for only 31.2%. By contrast, US and EU firms locate 78.5% and 69.3% of their overseas R&D centers[27], respectively, within these innovation hubs. This spatial mismatch substantially weakens Chinese firms' access to frontier knowledge spillovers and high-end innovation networks. Participation in international collaborative research further reflects these integration shortcomings. Between 2022 and 2024, the number of Chinese firms involved in global "Big Science" initiatives and multinational R&D alliances was only 23.1% of the US level and 29.4% of the EU level. Furthermore, such participation has been largely confined to applied technology domains, with international collaboration in basic research accounting for less than 15% of total involvement.

In terms of international talent cooperation, China's centrality score within the global inventor mobility network reached 49 in 2023, an improvement relative to 2020, yet still substantially lower than that of the United States (76) and the European Union (68). By 2024, overseas R&D personnel constituted only 6.8% of the workforce of leading Chinese firms, compared to 24.5% for US firms and 19.2% for EU firms[28]. Furthermore, international talent mobility has become more constrained: returnee growth among overseas-trained R&D personnel slowed sharply in 2023 (down 15 percentage points from 2020 levels), and the outflow risk for China's high-end domestic talent has increased. Both trends have directly eroded the talent pipeline needed for disruptive innovation (Han et al., 2024).

A significant imbalance persists in China's two-way cross-border technology flows as well, with both the quality and efficiency of technology transfer remaining suboptimal. In 2022, the ratio of technology import contract value to technology export contract value for Chinese firms stood at 3.7:1, markedly higher than the corresponding ratios of 1.2:1 for the United States and 1.1:1 for the European Union. Although this ratio declined to 3.2:1 in 2023 and further to 2.9:1 in 2024, the gap relative to advanced economies remains substantial. From a qualitative perspective, disparities are even wider. Between 2022 and 2024, core technologies accounted for only 18.6% of China's imported technologies, which were predominantly concentrated in mid-range application segments. In contrast, core technologies represented 59.7% and 48.3% of technology imports in the United States and the European Union, respectively. On the export side, Chinese technology outputs are largely concentrated in downstream digital applications and mid- to lower-tier segments of the new energy industry, with core patented technologies accounting for only 7.3% of total exports, far below the shares of 32.5% for the United States and 27.8% for the European Union. Although technology licensing transactions between Chinese firms and their US and European counterparts reached 33 deals in 2025, double the number recorded in 2019, the total transaction value amounted to only 11.2% of intra-EU licensing transactions and 8.9% of those among US firms[29]. Overall,

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[27-29] Source: Grassano et al., "The 2022 EU Industrial R&D Investment Scoreboard," 13 Dec., 2022, https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard; Georgakaki et al., "The 2025 EU Industrial R&D Investment Scoreboard," 22 Dec., 2025, https://iri.jrc.ec.europa.eu/scoreboard/2025-eu-industrial-rd-investment-scoreboard.

both the scale and technological sophistication of China's cross-border technology transfers remain limited, thus constraining the ability of international cooperation to generate efficient technological iteration and meaningful value creation.

4. Recommendations for Innovation Development during the 15th FYP Period: Deepening and Upgrading the Systematic Leapfrogging Catch-up Model

China must pursue a comprehensive deepening and upgrading of this systematic model in order to address the prominent barriers to innovation during the 15th FYP period. This entails leveraging technological complementarity as the foundation to correct resource allocation imbalances, positioning paradigm shifts as the core driver to overcome quality and efficiency bottlenecks, and strengthening ecosystem synergy as the institutional safeguard to unleash innovation vitality. Together, these coordinated efforts can help to forge a new innovation landscape characterized by nationwide coordination, source-level breakthroughs, institutional adaptability, and open, mutually beneficial cooperation.

4.1 Deepening Technological Complementarity: Constructing a Cross-Regional, Cross-Industrial, and Transnational Resource Integration System

Advancing deep-level regional technological complementarity. China should anchor efforts in building a unified national market to eliminate local protectionism and market segmentation while also establishing a robust cross-regional innovation coordination mechanism built on radiative spillovers, mutual empowerment, and equitable benefit sharing. The spillover effects of the country's major innovation hubs, such as Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area, must be fully harnessed. In particular, the integrated "innovation outposts + pilot testing base + industrial park" model should be scaled up nationwide. Policymakers should introduce targeted incentives, including tax preferences and revenue-sharing arrangements, to encourage enterprises from China's eastern region to transfer advanced and applicable technologies to the central and western regions. In addition, China should establish regional science and technology innovation centers and disruptive-technology pilot testing bases in the central and western regions to strengthen research infrastructure, industrial support systems, and capabilities for technology absorption and secondary innovation. For traditional industrial bases, such as those in Northeast China, innovation-driven revitalization should be accelerated through close collaboration with eastern innovation hubs, which should enable the transfer of advanced technologies and management practices to support industrial upgrades and the cultivation of emerging industries. To sustain effective cooperation, China must institutionalize strong cross-regional benefit-sharing and risk-sharing mechanisms, with returns clearly allocated based on innovation inputs and contributions. In parallel, cross-regional talent-sharing platforms, including joint appointments, exchange programs, and co-established training bases should be promoted to facilitate the free flow of innovation talent and knowledge diffusion. These measures can help to address regional talent imbalances and unlock the full potential of nationwide technological complementarity.

Strengthening inter-industry technological integration and multi-actor collaboration. China should prioritize strategic domains facing “chokepoint” constraints, including integrated circuits, industrial machine tools, and high-end scientific instruments, by establishing innovation consortia led by flagship enterprises and supported by upstream/downstream partners, universities, and research institutes. These consortia must break through technical barriers in foundational materials, core components, software systems, and related links to build strong full-chain innovation capacity. Concurrently, digital and green technologies should penetrate deeply into traditional industries, and emerging sectors must actively absorb engineering expertise and process know-how from established ones, creating a two-way empowerment dynamic that upgrades legacy industries and scales new ones. Looking forward, strategic positioning in frontier fields such as quantum technologies and brain-computer interfaces is essential. Establishing early complementarity channels that link future and existing industries will secure critical technologies and application scenarios ahead of time. Finally, enterprises should be encouraged to pursue cross-industry R&D, with targeted support for collaborative innovation across science-based, scale-intensive, and supplier-driven sectors, expanding application frontiers and fostering cross-domain knowledge fusion conducive to disruptive breakthroughs.

Expanding diversified international technological cooperation. China must pursue a balanced approach of “bringing in” and “going out” that deepens cooperation with developed countries in basic research through joint laboratories and collaborative efforts on frontier scientific problems. Additionally, Belt and Road science and technology cooperation should be intensified in advantageous fields such as new energy and 5G by launching demonstration projects that promote technology export, joint standard development, and capacity building, thereby enhancing the global influence of China’s independent innovations. Enterprises should be encouraged to set up R&D centers in overseas innovation hubs, engage in major international big science programs and multinational R&D alliances, and establish high-level joint laboratories and technology transfer centers to integrate global resources and counter pressures from international technological containment. Active participation in ISO, IEC, ITU, and other standardization bodies is essential for leading or contributing to international technical standards and advocating fair global IP protection systems, thereby strengthening China’s voice in global innovation governance. Finally, robust mechanisms must be built to address high-tech frictions, including a monitoring and early-warning platform, coordinated responses from government, enterprises, and industry associations, enhanced corporate compliance training and certification, and firm opposition to trade protectionism and technological blockades via multilateral frameworks to safeguard legitimate enterprise rights and interests.

4.2 Focusing on Paradigm Shifts: Strengthening Systemic Leadership in Disruptive Innovation

China should prioritize paradigm shifts by consolidating the foundations of original innovation, overcoming critical technological bottlenecks, and breaking entrenched path dependencies, thereby enabling disruptive innovation to reconfigure technological systems and industrial structures, propelling the leap from catch-up to parallel advancement and eventual global leadership.

To solidify the base of basic research and original innovation, sustained increases in basic research funding are essential. Specifically, this funding target should be a share exceeding 15% of total R&D expenditure by the end of the 15th FYP to approach levels in advanced economies. Basic research layout should be optimized by bolstering the concentrated R&D capabilities of National Laboratories and Frontier Science Centers, with focused support for frontier domains including quantum science, life sciences, and foundational AI theories. A long-cycle, originality-first evaluation system must replace quantity- and publication-centric metrics, granting researchers greater autonomy in technical directions and funding use, and failure-tolerant mechanisms should be instituted to encourage high-risk, high-reward original work and nurture disruptive innovation at the source.

Furthermore, to surmount core technological bottlenecks, China should, by leveraging the new-type national system, integrate innovation resources from enterprises, universities, and research institutes to establish cross-departmental and cross-regional consortia for disruptive breakthroughs. Specialized funds, modeled on the National Integrated Circuit Industry Investment Fund, should target chokepoint areas such as semiconductors, EDA software, and high-end GPUs and employ "open competition" and "horse-racing" mechanisms to concentrate resources on full-chain attacks. Scientific infrastructure must be strengthened through expanded proof-of-concept and pilot-scale platforms to bridge the persistent gap from laboratory outcomes to industrial products. Market demand should be harnessed by opening large-scale application scenarios in smart manufacturing, intelligent transportation, and healthcare, accelerating iterative upgrades and paradigm transitions.

To dismantle technological path dependency, coordinated policy guidance and market mechanisms should facilitate smooth transitions between old and new paradigms. In energy and manufacturing sectors, fiscal subsidies, tax incentives, and market-access policies should favor emerging paradigms while constraining outdated ones. Traditional industries should be propelled toward high-end, intelligent, and green transformation through integration of AI, industrial robotics, and new energy technologies. Market forces should play their decisive role through strengthened oversight and fair competition rules that prevent monopolies from blocking new paradigm diffusion, and enterprises should be encouraged to explore frontier technologies and reduce reliance on mature paths in order to foster diversified technological development.

Finally, to enhance patent quality and international standard-setting discourse power, China should establish synergistic mechanisms that link R&D, patent strategy, standard formulation, and industrial application, directing innovation actors toward high-value patent deployment around core technologies and curbing low-quality patents. In comparative-advantage fields such as AI, quantum communication, and new energy, China should lead international standard formulation, embed indigenous innovations into global rules, and cultivate proprietary-standard-based ecosystems. The national standards system should align more closely with international best practices, with deeper participation by enterprises and universities in global standardization activities, thereby consolidating technological leadership through strengthened normative influence in international governance.

4.3 Strengthening Ecosystem Synergy: Refining the Institutional Support and Guarantee System

To optimize ecosystem synergy, China must prioritize institutional reform, enhanced factor support, and the cultivation of a supportive innovation environment. These efforts can work together to create a high-efficiency, stable, and sustainable institutional foundation for technological complementarity and paradigm shifts.

Deepening reforms of the science and technology system and its evaluation mechanisms.

China should continue advancing the “Three Evaluations” reform by establishing a performance-based assessment framework centered on innovation capability, quality, effectiveness, and real-world contribution. This requires a decisive break from evaluation practices dominated by publication counts, patent numbers, and awards. Enterprises should be further consolidated as the primary drivers of technological innovation. Leading firms should be encouraged to take charge of major national science and technology projects, with expanded autonomy over funding allocation and technological roadmaps to enhance market-oriented innovation efficiency. A clearly defined fault-tolerance and error-correction framework should be established for high-risk, long-cycle disruptive innovation activities. By adopting long-horizon, outcome-oriented tracking evaluations, policymakers can remove institutional pressures on researchers and enterprises, reduce innovation-related anxieties, and incentivize the pursuit of transformative, high-impact research.

Improving intellectual property protection and commercialization system. Protection for core technologies and original innovations must be significantly strengthened. Strict enforcement of punitive damages for patent infringement, faster litigation timelines, and higher infringement costs can improve enforcement credibility and safeguard innovators’ legitimate rights. Dedicated fast-track examination channels should be created for disruptive patents, particularly in frontier fields such as artificial intelligence and quantum information. Tailored examination standards and streamlined review processes can substantially accelerate patent approval in emerging domains, and national-level intellectual property trading platforms and valuation centers should be developed to integrate services such as patent navigation, transaction facilitation, and commercialization support. Benefit-sharing mechanisms for researchers should also be refined to improve the market-based conversion efficiency of research outputs.

Optimizing technology finance and talent support systems. A full-lifecycle financing ecosystem should be built that encompasses angel investment, venture capital, industrial funds, and capital markets. A National Disruptive Innovation Guidance Fund should be established to channel social capital toward basic research and frontier technologies. Financial innovations, including intellectual property-backed lending and technology insurance, should be expanded alongside risk-sharing and compensation mechanisms in order to raise financing accessibility for technology-based small and medium-sized enterprises. The “hard technology” orientation of the STAR Market should be further clarified, and differentiated institutional arrangements for the ChiNext Board and Beijing Stock Exchange should be refined to support pre-profit firms with core technologies. Talent policies should prioritize the cultivation and global recruitment of top-tier leaders in frontier fields such as AI and quantum science, along with improved facilitation of cross-border mobility. Universities and research institutes should expand interdisciplinary innovation programs to nurture composite talent profiles. The promotion of the scientific spirit, the entrepreneurial spirit, and craftsmanship can help foster a social ethos that encourages innovation while still tolerating failure, thereby strengthening the foundation of the national innovation workforce.

5. Concluding Remarks

The 14th FYP period witnessed China’s successful establishment of, a systematic leapfrogging catch-up model for innovation, characterized by technological complementarity as the foundation, paradigm shifts as the core, and ecosystem synergy as the safeguard. This model has enabled a critical transition from extensive scale expansion to simultaneous improvements in quality and efficiency and provided an effective pathway for technological catch-up in latecomer economies. The mutually nested and reinforcing interaction among these three dimensions has significantly elevated R&D intensity, patent quality, and the strategic capacity of China's innovation clusters.

Looking ahead to the 15th FYP period, further deepening and upgrading this systematic model are essential to achieving a new wave of technological breakthroughs. Technological complementarity must evolve toward comprehensive national-level integration. Paradigm shifts should be strengthened through coordinated, system-wide leadership, and ecosystem synergy must place greater emphasis on institutional innovation. The synchronized advancement of these three dimensions can help overcome persistent bottlenecks in core technologies and address regional imbalances in innovation capacity.

In the future, China must integrate into the global innovation network with greater openness, expand strategic space through technological complementarity, seize first-mover advantages through paradigm shifts, and consolidate collective strength through ecosystem synergy. These efforts are expected to accelerate the emergence of disruptive innovations, inject powerful momentum into the development of new quality productive forces, and provide a solid technological foundation for realizing socialist modernization by 2035. CE

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