Innovation-Driven Development in China: Catch-Up and Beyond

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Abstract: *Since the adoption of the reform and opening-up policy in 1978, China has pursued an innovation-driven development strategy. After decades of catching up with advanced nations, China is taking the lead in certain technological advancements and shifting from dynamic secondary innovations under open conditions to original innovations at a higher level of openness. In a new round of technological and industrial revolutions, shorter technological lifecycles and ever-changing technological paradigms present a strategic window of opportunities. Based on our review of the emerging driving forces of smart manufacturing and unicorns, we suggest that China urgently needs to develop a new national innovation system to help its companies take the lead and bypass the constraint of existing technology paradigms to seize emerging opportunities. This paper provides a theoretical guidance for China's innovation-driven high-quality development. Looking ahead, we suggest that innovation-driven development must adapt to rapidly changing trends.*

Keywords: *Innovation-driven development, paradigm shift, technological catch-up, beyond catch-up*

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In its 125th anniversary series, *Science* posed 125 of the most difficult questions in global science. One question that came up was "Why do some countries grow and others stagnate?" (Kerr, 2005). In general, developing nations are less technologically advanced than developed nations and must learn from developed nations in order to catch up. Despite the persistence of this learning process and the constant progress of developing nations, there are still some technological gaps with developed nations. In contrast to the unfortunate "middle-income trap" that befell some Latin American and Southeast Asian nations, China has largely succeeded in closing its technological gap with advanced nations, and in certain domains has even outperformed them. China's economic growth marvel is both typical and unique, and is difficult to be explained using traditional Western theories. What factors are responsible for China's economic growth? Since reform and opening-up, the innovation-driven emergence of corporate champions led by Huawei has illuminated this question.

1. Achievements of Innovation-Driven Development: Economic Performance since Reform and Opening-up

1.1 Innovation as the Primary Driving Force of Growth

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Since the inception of reform and opening-up in 1978, China's economy has made remarkable strides and maintained a high growth rate. From 1978 to 2022, China's GDP growth averaged 9.5%, surpassing the global average by a wide margin. As depicted in Figure 1, China is currently the second-largest economy in the world and is rapidly closing up to the United States, the world's largest economy. China proactively develops international trade. Since its entry into the WTO, China's exports have steadily increased. In 2022, China's total import and export volumes of goods amounted to 42.07 trillion yuan, with exports of goods representing close to 15% of the global market share. China has been the world's largest commodities trading nation for six years running. With 666 types of industrial activity in 207 subcategories of 41 industrial categories, China is the only country in the world to have all industrial sectors according to the United Nations industry classification system. Industrial value-added in China reached 40.2 trillion yuan in 2022, accounting for 33.2% of GDP. This comprises a manufacturing value-added of 33.5 trillion yuan, which accounts for 27.7% of its GDP. China has been the world's largest manufacturing nation for the past 13 years. In 2022, China accounted for nearly 30% of world total manufacturing value-added, while the US accounted for only 16%. Upon its entry into the WTO in 2001, China accounted for only 6% of global manufacturing value-added, placing it far behind the US, which ranked first globally.

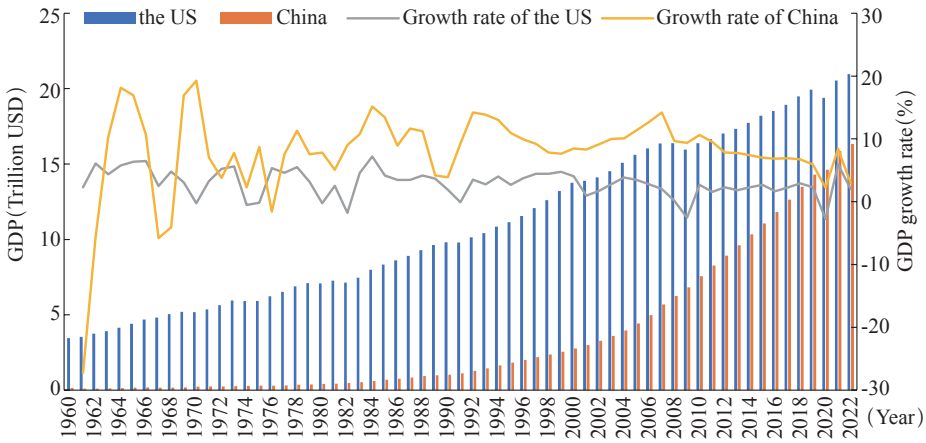

Figure 1: GDP and Growth Rates of China and the US (1960-2022, in constant 2015 US dollars)
Source: Drafted by authors according to the World Bank's data.

As shown in Figure 2, a comparison of industrial value-added growth rates for China and the US after China's 1978 reform and opening-up reveals a strong correlation between the two, in stark contrast to their mutual independence of industrial development before 1978. On the one hand, China and the US complement one another in the international division of manufacturing labor. The US is more competitive in high-end manufacturing, whereas China has comparative advantages in low-end manufacturing. Cooperation between the two nations along the global manufacturing value chain will affect the growth rate of manufacturing value-added in each nation. On the global commodities market, however, China and the US are interdependent. The US is China's largest export market, and China is a manufacturing hub for the US. The manufacturing value-added growth rate of each nation will be affected by the level of economic development in the other nation. Made-in-China products are so prevalent in the US that the absence of China would come at a great expense of American consumers in terms of convenience and cost (Bongiorni, 2007).

The question is that what made it possible for China to achieve its economic miracle based on the "worst theory" as described by Western mainstream economics. How did China maintain such

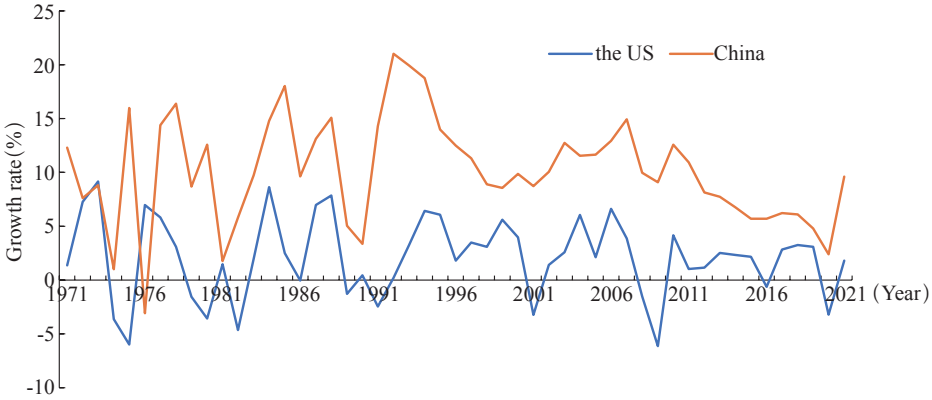

Figure 2: Industrial Value-added Growth Rates of China and the US (1971-2021, in constant 2015 US dollars)

Source: Compiled by the authors based on data from the UN.

a rapid growth rate? Is it because of what appears to be the "worst policy" in Western eyes? Or is it due to China's late-mover advantage and income disparities with high-income nations (Lin, 2019)? Technology innovation, a relatively rare local source of production, turns out to be the primary driver of economic growth in China, a labor-intensive economy with a sufficient low-cost advantage. China's rapid development is a result of a practical and innovation-driven approach, as shown by the country's experience with reform and opening-up. The transition from factor- and investment-driven to innovation-driven growth has been the driving force behind China's escape from the "middle-income trap" (Wu and Wu, 2018).

In 2022, China's R&D expenditures reached 3.1 trillion yuan, second only to those of the US, a 10.4% increase over the previous year. China's R&D spending as a share of GDP increased from 1.45% in 1978 to 2.55% in 2022, with double-digit growth rates for seven consecutive years, and spending on basic research reached 200 billion yuan. Spending on basic research as a share of GDP has exceeded 6% for four consecutive years since 2019. China has one of the highest R&D spending growth rates in the world, despite the internationally modest proportion of R&D spending to GDP. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development*, in 2022, China approved 4.323 million patents and accepted 74,000 patent applications under the PCT with 17.879 million valid patents, including 3.28 million valid domestic invention patents. China has led the world in the number of patents since 2011, establishing itself as an intellectual property rights (IPR) powerhouse.

1.2 Growing Business Champions

A robust economy is supported by robust corporations. From one in 1989, the number of Chinese companies on the Fortune Global 500 list increased to 129 in 2019, surpassing the 121 of the US. Historically, Japan came closest to the US, with 149 companies on the list, compared to 151 of the US in 1995. Since then, the US has held the No. 1 position for many years, while Japan has slipped over the last two decades. In 2022, there were 145 Chinese companies (including 28 private companies, or 1/5 of the total) on this list, surpassing the 124 companies of the US and 47 companies of Japan. These Chinese companies represented 31% of the total business revenues of the Global 500, surpassing the US for the first time. This change reflects the decline of Western centrism and ushers in a new era in which Chinese companies compete with multinational Western firms on the same stage.

Growth of Chinese companies has been accompanied by a sharp improvement in their innovation performance. Chinese technology companies among top 50 on the Boston Consulting Group's (BCG)

annual list of the world's most innovative companies for 2022 include: Huawei (8th), Alibaba (22nd), Lenovo (24th), JD.com (30th), Xiaomi (31st), and Tencent (41st). Nineteen Chinese companies joined the rank of top 100 global companies with the highest R&D spending in 2022 as shown in the *2022 EU Industrial R&D Investment Scoreboard*. With an R&D investment equivalent to 19.5 billion euros, Huawei ranked first among Chinese companies and fourth globally. Other Chinese companies on the list include Alibaba (17th), Tencent (18th), China State Construction Engineering Corporation (34th), Taiwan Semiconductor Manufacturing Company (48th), Baidu (53rd), China Railway Corporation (54th), Hon Hai (55th), China Communications Construction (56th), MediaTek Inc. (59th), SAIC Motor (61st), China Railway Construction Corporation (62nd), ZTE (70th), Meituan (82nd), Power Construction Corporation of China (85th), Metallurgical Corporation of China (91st), PetroChina (92th), Kuaishou Technology (94th), and NetEase (98th).

Without a world-class market, there would have been no world-class corporations. China has embraced new technologies and the new economy in the emerging digital economy in order to capture the strategic window of opportunities presented by a new round of technological and industrial revolutions (Wu et al., 2019). According to the *51st Statistical Report on China's Internet Development Status*, China has 1.067 billion internet users, or 21.56% of world total, making it the largest internet-based society in the world. There are currently 911 million paid internet users and 845 million online consumers. The volume of online retail transactions in China is 13.79 trillion yuan, compared to 1.09 trillion dollars in the US. China's online retail sales volume accounts for 37% of world total, constituting 31.34 % of its total consumer products retail sales volume of 44 trillion yuan. China has constructed the world's largest and most advanced mobile communications network, with 1.683 billion mobile phone users, of whom 561 million (33.3%) are 5G mobile phone users. This ratio is one of the highest worldwide. The value of China's mobile payment market is 5.5 trillion US dollars, while the same figure for the US is only 110 billion US dollars. There are 159 publicly listed internet companies in China with a combined market capitalization of 10.3 trillion yuan. China's digital economy is worth 50 trillion yuan, or over 40% of its GDP. In terms of total computing capacity, China's operational data centers contain over 6.5 million standard racks, ranking them second in the world. Of critical processes at key industrial enterprises, 58.6% are digitally controlled, and the penetration of digital R&D tools has reached 77%.

China has become the world's second-largest digital economy over the past four decades of reform and opening-up by integrating global technological innovations and focusing on digital technology applications and use case innovations despite being a late mover. China has fostered a large number of world-class digital economy companies, including Huawei, Alibaba, Tencent, and Baidu, in a variety of fields. By absorbing the largest user base in the world, China has created a thriving digital innovation ecosystem that integrates the digital economy with the real economy, giving rise to new industrial and business models such as smart manufacturing, industrial internet, connected vehicles, and the platform economy. Numerous ecosystems and business models have supported innovations in technology.

1.3 Innovative Entrepreneurs

China's economic success is more attributable to corporate innovation and the underlying ethos of entrepreneurship. During the past four decades of reform and opening-up, a large number of exploratory and innovative entrepreneurs have arisen and played a crucial role in China's economic development, making significant contributions to China's economic transition and innovation-driven development. China has taken steps to establish enterprises as the foundation of innovation, with innovative entrepreneurs at the helm. Enterprises have started to play a pivotal role in market competition and the integration of innovation and industrial chains. Entrepreneurs spearhead the market-based supply of technology and innovate to stay competitive. Moreover, they closely follow and swiftly respond to market changes in order to provide more innovative products and services.

Despite relative disadvantages in technology, human resources, and capital compared to

multinational corporations from developed nations, Chinese enterprises have gained greater market recognition and competitive advantage due to their entrepreneurial spirit and relentless consolidation of internal and external resources, which resulted in the creation of innovative products and services with superior quality, efficiency, and cost-effectiveness. During this phase of industrial development, they imported complete sets of mature technology and accelerated the commercialization and localization of imported technologies. In this way, Chinese entrepreneurs supplied the local market with suitable technologies, created jobs, established a foothold on the international market, and accelerated China's emergence as the world's factory floor. In the new wave of industrial development, they explored new technologies and global markets with audacity, raced to catch up to industry leaders and increase innovation dynamism, and grasped the strategic opportunities presented by a paradigm shift. As a result, they have shaped new technological paradigms, fostered independent innovation capabilities, attained cross-cyclical development, and attracted and nurtured a large number of innovative talents. With an entrepreneurial spirit, enterprises have consistently propelled technology advancement, industry upgrade, and industrial development toward high-end manufacturing and high value-added, thereby contributing to economic growth, social progress, and international competitiveness.

1.4 Cross-Cyclical Industrial Growth Model

In some technology industries, China has demonstrated a discrete growth process, which is essentially a long-term growth model characterized by step changes in technology paradigm and deep-seated structural transition. Taking the display industry for instance, China has evolved from a laggard in CRT to a follower in LCD panels and a leader in OLED panels. Through consistent R&D input, BOE Group, for instance, has taken full advantage of the window of strategic opportunities from a technology paradigm shift, making a success story of cross-cyclical growth. When BOE Group was established in 1993, the global LCD panel technology was still in its nascency. Back then, advanced economies like Japan and South Korea held an absolute advantage in LCD. BOE, a global leader in the semiconductor displays market, has played a pivotal role in the establishment and development of China's display industry. Currently, one in four smart devices in the world is equipped with a BOE screen. According to Omdia, a technology research firm, BOE ranks first in the world in terms of LCD shipments for the five application sectors of smart phones, tablets, laptops, monitors, and televisions. By 2022, BOE had cumulatively submitted 80,000 patent applications. IFI CLAIMS, a US-based patent services company, ranked BOE eleventh worldwide in its statistical report of US patent authorizations in 2022, making it a top 20 global patent applicant for the fifth consecutive year. With 1,884 PCT patent applications, BOE is ranked 7th worldwide in the 2022 World Intellectual Property Organization (WIPO) ranking of global patent applicants. This makes BOE one of the top 10 global PCT patent applicants for the seventh year in a row. Moreover, it has made key breakthroughs in flexible display and other new emerging technological fields, contributing to China's emergence as a high-end manufacturing powerhouse.

China has also experienced cross-cyclical development in the ICT industry, which is led by Huawei. Prior to the founding of Huawei in 1987, the Chinese ICT market was dominated by multinational corporations from "seven countries with eight standards". Namely, there were eight models of equipment from seven countries, including NEC and Fujitsu from Japan, Lucent from the US, Nortel from Canada, Ericsson from Sweden, Siemens from Germany, BTM from Belgium, and Alcatel from France. Among them, Japan's NEC and Fujitsu accounted for two standards. Huawei's history of catching up in the ICT domain can be characterized as a process of constant innovation and breakthrough under various technology paradigms, transforming from a 2G laggard to a 3G follower, a 4G forerunner, and a 5G pacesetter (Wu et al., 2020). Through constant technological advances and R&D investments, Huawei has caught up with and in some instances even surpassed Cisco and Ericsson as the world's leading telecom gear maker. Huawei's constant innovations and advancements in areas such as artificial

intelligence (AI), cloud computing, and the internet of things (IoT) have contributed to China's rise in the global high-tech industry. Huawei has adopted an innovation strategy that is open, collaborative, and win-win. Today, Huawei is a prominent global provider of ICT infrastructure and smart devices, with 207,000 employees and business operations in more than 170 countries and regions serving some three billion people. In 2022, Huawei earned 642.3 billion yuan in global business sales and invested 161.5 billion yuan in R&D, accounting for 25.1% of total annual income. Over a decade, Huawei has spent more than 977.3 billion yuan on research and development. Huawei employs 114,000 R&D personnels, which accounts for 55.4% of its total workforce, and possesses over 120,000 patent authorizations worldwide. It has submitted over 68,000 standard proposals to more than 200 standard organizations, collaborating with domestic and international customers and industrial partners to advance global technological progress and industrial modernization. Installations of Huawei's EulerOS have surpassed 3 million units. HarmonyOS, developed by Huawei, has been installed on over 330 million devices. HarmonyOS has over 2 million developers and over 2300 partners in its smart device ecosystem.

2. Evolution of Innovation-Driven Development: Technological Catch-Up and Secondary Innovation

2.1 Technological Catch-Up in the Chinese Context

In terms of indigenous innovation and technological catch-up, Chinese companies exhibit distinctive characteristics. The first one is context-specificity: Chinese enterprises catch up with industry leaders in the Chinese context, which is distinct from the context for advanced economies and emerging industrialized nations. The second one is a new development environment: Chinese enterprises have embraced a global and network-based open environment, redefining the concept of indigenous innovation. Targeting emerging technologies, Chinese-style technological catch-up occurred in multiple phases across a diverse range of sectors at various levels. In the Western context, it was original innovations that brought Western companies to the global frontiers. In the context of emerging industrialized nations such as Japan and South Korea, however, their businesses have completed technological catch-up from imitation to innovation (Hobday, 1985; Kim, 1997; Lee and Lim, 2001). During their initial stages of development, Western multinationals benefited from a stable political environment, complete technology systems, and flourishing market economies in the absence of a global network. Emerging industrialized nations like Japan and South Korea had their governments take the lead in catching up in technology; national technology systems dictated corporate research and development; and exports were geared primarily toward the European and North American markets.

Unlike Western developed countries and latecomers such as Japan and South Korea, Chinese enterprises have pursued indigenous innovation and technological catch-up in the Chinese context of transitional ownership system, diversified technological systems, multitiered market space, and emerging global networks. These distinguishing characteristics have defined China's homegrown creativity and technological catch-up (Wu and Wu, 2013). First, global networks primarily include foreign direct investment (FDI), export spillovers, global value chains, manufacturing networks, and outward foreign direct investment (OFDI) during Western crises. Second, the context of technological opportunities includes a rapid shift in technological paradigm and the emergence of disruptive technologies. Third, domestic market opportunities arise from China's multitiered domestic market based on its low-cost advantage, complex market structures, and large domestic demand. The extensive technology and business model innovations in China's business community serve as a prime example of the country's way of technological catch-up. Unlike previous technology-focused catch-up efforts, China's comprehensive catch-up strategy should incorporate system, technology, market, and network. In certain instances, breakthroughs have been made first in markets, institutions, and peripheral technologies.

China regrettably fell behind in numerous industrial revolutions due to historical circumstances. China's technological catch-up requires extensive indigenous innovations to compensate for its missed opportunities during the three industrial revolutions that ushered in the eras of steam engines, electric power, and information technology. The Fourth Industrial Revolution, led by the ABCDE (artificial intelligence, block chain, cloud computing, data tech, and edge computing), provides China with strategic opportunities for a paradigm shift. It is both necessary and possible for China to seize this window of opportunities based on its knowledge and experience from decades of indigenous innovation. Relentless research, development and innovation are the only way for China to bypass existing technology paradigms established by Western powers, bolster its manufacturing strength, and achieve technological independence and sustainable development.

2.2 Dynamic Process of Secondary Innovation

Western nations focused more on original innovation stemming from basic research, trying to create or disrupt an entire industry with one invention or new product China has embarked on a path of "secondary innovation", i.e., creative development on the basis of technology acquisition and assimilation.

Based on the concepts of "technology paradigm" and "technology track" proposed by Dosi (1982), Wu (1995) defined "secondary innovation" as "technology innovation based on technology importation within an existing technology paradigm and along an existing technology track". Based on the technology lifecycle model developed by Utterback and Abernathy (1975), Wu (1995) devised a dynamic process model of secondary innovation, as depicted in Figure 3. The dynamic process of secondary innovation suggests that in the early phases of development, late-mover businesses should introduce Type I technologies (mature technologies) and enhance technological capabilities through the three stages of secondary innovation. After enterprises have accumulated sufficient knowledge and experience through multiple rounds of secondary innovation, they may begin to introduce Type II technologies (emerging technologies or laboratory technologies) by seizing the window of strategic opportunities from a paradigm shift (i.e. Beyond Catch-up I) or even initiate a new round of innovation (i.e. Beyond Catch-up II). In this sense, Beyond Catch-up means bypassing an existing technology paradigm, as opposed to the conventional catch-up along a technological track. Beyond Catch-up occurs in the context of a paradigmatic shift in technology, in which the new technology is still in the early stages of lifecycle. This creates conditions for industry late-comers to catch up to industry leaders in terms of technological capabilities.

"Secondary innovation" is a dynamic process of accumulation and evolution. On the basis of the importation of mature technologies, "secondary innovation" can be approximately categorized into three stages: Stage I: Imitative innovation, or the mastery of a new technology that is not presently available on the local market through importation, imitation, learning by doing, or reverse engineering in order to manufacture the same product. After the previous stage of planning, accumulation and assimilation, Stage II is creative imitation, which involves indigenous innovation and local manufacturing for import substitution. Stage III is improvement innovation: The technology importer masters the principles and use of the new technology through assimilation and re-innovate. In this stage, the product's technical and economic performance is comparable or even superior to that of products from developed nations, making it highly competitive. The key to the success of "secondary innovation" is avoiding repetitive technology importation at a low level that leads to a vicious cycle of importation, falling behind, re-importation, and falling behind again. Throughout the process of learning, the technology importer establishes its own innovation management system for catch-up and beyond. This necessitates the importation of emerging or laboratory technologies, as well as early-stage exploratory R&D interventions for the "post-secondary innovations" of emerging or laboratory technologies, or even the initiation and leadership of the "original innovation" of emerging technology paradigms.

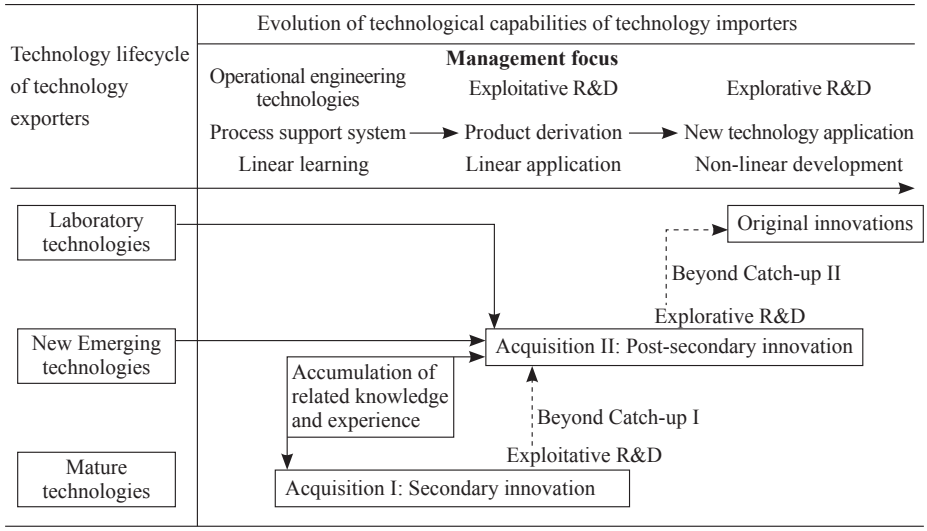

Figure 3: Evolving Path of Innovation-Driven Development

Source: Adapted from Wu (1995).

Secondary innovation presents unique benefits in comparison to original innovation. The first is late-mover advantage. Less uncertainty in technology and the market reduces the difficulty of R&D and the amount of human, financial, and material resources required, obviating the need for extended R&D efforts and repeated tests to achieve crucial progress in technology. In certain instances, innovations combining imported and existing technologies can be realized for a specific target market with a strong expectation of profit. Therefore, the R&D and production cycles of secondary innovations are shorter, less expensive, and simpler to commercialize. Second, secondary innovation is comprised of re-innovations of existing technologies, such as process, integrated, and iterative innovations. Businesses progressively acquire all or a portion of essential technologies and intellectual property rights through secondary innovations in order to sharpen their competitive edge. Obviously, secondary innovation cannot be directly transformed into original innovation for the following reasons: On the one hand, technological catch-up must be conducted under a technology paradigm established by Western developed countries; on the other hand, the late-comer must transcend the constraint of mature technology paradigms (Xu et al., 2019). In the midst of the latest technological and industrial transformations, the emergence of new technologies and business models has opened a window of opportunity for the late-comers (Wu et al., 2019), which are the driving force behind innovation. Their ground-breaking innovations in critical industrial sectors and processes play a crucial role in fostering China's ingenuity, comprising an integral part of the country's innovation system.

3. New Forces of Innovation-Driven Development

3.1 New Forces of Smart Manufacturing

China is becoming a dominant force in IoT and AI. The Fourth Industrial Revolution, unlike physical production in the eras of mechanization, electrification, and automation, is characterized by the integration of industrialization and informationization. China is pursuing the new directions of smart manufacturing enabled by digitalization, IoT, and AI, in competition with Germany's Industry 4.0 and the US industrial internet from the same start line (Wu, 2015). China has started exploratory research on next-generation information technologies, advanced CNC machine tools, robots, power equipment, agri-equipment, new materials, aviation and aeronautics equipment, turbines, shipbuilding, rail transportation

equipment, new energy vehicles, biomedicine equipment, and high-performance medical devices.

Meanwhile, China is strengthening its manufacturing capabilities by: (i) Promoting innovation to reduce reliance on imported technology; (ii) imposing stricter quality and technical requirements for critical components to reinforce the industrial foundation; (iii) pursuing sustainable, low-carbon, and eco-friendly development; (iv) improving industrial structure and promoting specialized, sophisticated, and differentiated development of small and medium-sized enterprises (SMEs); and (v) adopting a talent-oriented approach to fully utilize talents as the primary resource and create a talent ecosystem that supports high-quality manufacturing.

To support these endeavors, China has established national manufacturing innovation centers with joint participation of the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), the Ministry of Science and Technology (MOST), and the Ministry of Finance. These national innovation centers are tasked with advancing China's manufacturing transition and upgrade, focusing on smart and high-end equipment manufacturing. The goal is to improve manufacturing quality, efficiency, and value-added. By 2022, China had built 26 national innovation centers for smart manufacturing, equipment manufacturing, new materials, and new energy vehicles. By consolidating resources for innovation synergy, these innovation centers have played a pivotal role in relevant fields, providing robust support for China's manufacturing transition, upgrade, and high-quality development.

3.2 Corporate Unicorns in Ascent

Corporate unicorns with an industrial heritage in China are ascending to the forefront. Corporate unicorns refer to start-ups with a valuation of over one billion US dollars, which are regarded as rare but crucial innovation drivers worldwide. According to Forbes China's 2022 list of new unicorns, the total number of global unicorns reached 1,597 in 2022, with 746 from the US (47%), 368 from China (23%), 246 from Europe (16.6%), and 103 from India (6.5%), which jointly make up 90% of the total. The multipolar unicorn market has taken shape, with new and clean energies, medicine, life sciences, and encryption technology as key innovation fronts. In 2022, 80% of the world's new unicorns arose from those sectors. China contributed over 70% of new unicorns in four domains in the same year. Clean and new energies contributed the most, followed by healthcare and smart logistics/mobility. In the meantime, corporate services and encryption contributed to more than half of the US's new unicorns.

The majority of Chinese unicorns are concentrated in finance, healthcare, education, and transportation sectors. Despite the high barriers of industry monopoly, these unicorns have seized the strategic window presented by paradigm shifts to establish a foothold in those monopolistic, high-profit sectors. Unicorns have forayed into even more conventional economic sectors, fueling the digital economy's boom. Unicorns also benefit from low thresholds to enter digital sectors, which are assets-light, low-cost, high-elasticity, and subject to fewer policy restrictions. In the tech sector, unicorns have adopted a new economic growth model driven by technology. New unicorns have flourished in the consumer sector as a result of consumption upgrade and relentless consumer pursuit of experience, quality and category.

4. Innovation-Driven Development and the National Innovation System

4.1 Revisiting the National Innovation System: A Fresh Perspective

China's innovation-driven development strategy should be deliberated as an inseparable part of its national innovation system. The triple-spiral theory of the national innovation system underscores interactions among universities, industries and the government. It has put forth a brand-new concept and path of innovation and economic development for a country to stay competitive globally. While R&D results provide industries with technical support and innovation dynamism, industrial and commercial

practices and market demand reinforce further development and innovation of scientific research. Policymaking facilitates industrial development and scientific innovations, forming a virtuous innovation ecosystem.

The new national innovation system presents such a trend: The demand side is extending from the mass market to the vertical and individualized market, and the supply side is extending from traditional large enterprises to small, medium-sized and micro businesses. A panorama of shared prosperity has been created by a confluence of economic factors. They include dominant forces, core competencies stemming from the market economy, as well as an open and all-encompassing digital ecosystem. This will be an era more tolerant of grassroots and inclusive innovations and services. In 2022, the number of mobile devices in China reached 3.528 billion with 1.845 billion mobile IoT users, representing 70% of world total. Through integration with the network-based digital economy, a brand-new innovation ecosystem becomes re-established, incorporating more innovation factors and themes. The national innovation system is an open and inclusive platform for collaborative innovation among grassroots innovators.

Science, technology, and innovation policies are essential components of the national innovation system. The new era imposes new requirements on policymakers regarding issues spanning from incentives to financial support, talent importation and IPR, with the goal of fostering innovation and entrepreneurship and boosting competitiveness and creativity. Infrastructure for innovation is another component of the national innovation system. Science parks, incubators, and technology transfer centers, for example, provide innovators with space, equipment, technical support, and talent training in order to accelerate innovation and commercialization. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development,* in 2022, China had 533 national key labs in operation, 191 national engineering research centers as part of the new series management, 1,601 national corporate technology centers, and 212 mass entrepreneurship and mass innovation demonstration bases. The national guidance fund for the commercialization of scientific and technological results has established 36 sub-funds totaling 62.4 billion yuan. Nationally, there are 1,425 technology enterprise incubators and 2,441 mass entrepreneurship spaces. The government is expected to play a greater role in public-private partnership (PPP) and guidance fund models. Technology transfer will be accelerated by maker space, innovation and entrepreneurship platforms, incubators, and other innovation vehicles. Overseas talent will inject innovative vitality into the new ecosystem. National laboratories will facilitate domestic innovation. These forces have become essential for the invention of new knowledge and technologies.

4.2 National Innovation System in the Era of the Digital Economy

As China opens more broadly in the context of globalization and digitalization, the rapid global flows of capital, technology, and human resources have become defining trends and shaped our new national innovation system. In the age of globalization and digitalization, the national innovation system promotes global economic integration and interconnectivity, trade and investment, economic growth and prosperity, international economic competition and cooperation, as well as innovation and talent cultivation in various countries. Meanwhile, new challenges and risks have surfaced:

The first is the national innovation system amid accelerating capital flows. As it becomes simpler for capital to flow across borders, investors may conduct cross-border investment and financing through the internet and digital platforms with relative ease. This development has accelerated the globalization process and strengthened economic relations and international competition. The influence of capital will predominate market reforms, and an increase in capital expenditures will propel the growth and prosperity of emerging industries. According to the *2022 EU Industrial R&D Investment Scoreboard 2022*, China, the US, Japan, and the European Union have distinct R&D investment priorities in various domains. In 2022, China's R&D investments were concentrated in the following industries:

ICT manufacturing (26.6%), ICT services (17.7%), construction (12.6%), industry (10.4%), others (9.7%), automobiles and other transportation (9.2%), the health industry (7%), energy (3.5%), chemical engineering (1.9%), finance (1%), and aviation, aerospace, and defense industry (0.3%). Particularly, China has greater global competitiveness in the areas of ICT manufacturing, industry, construction, and energy R&D investments.

The second is the national innovation system amid accelerating technological progress. In the context of globalization and digitalization, it has also become easier for technology to migrate across borders, making technology exchange and cooperation between nations more common and intimate than ever before. This trend has increased international cooperation and competition while facilitating global technological innovation and application. According to *the 2022 PCT Annual Review of the World Intellectual Property Organization (WIPO)*, Huawei ranked first among the top 20 global commercial PCT applicants in 2021 with 6,952 patents, followed by Oppo (6^{th}), BOE (7^{th}), Ping'an (11^{th}), ZTE (13^{th}), Vivo (16^{th}), and DJI (20^{th}). Chinese companies comprise one-third of the top twenty.

The third is the national innovation system amid accelerating talent migration. Increasing levels of education worldwide and a more permissive immigration policy have facilitated the movement of talents across borders. This trend has increased human resources cooperation and exchange between nations, as well as the global competition and flow of talent. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development*, in 2022, China had 3.654 million postgraduate students on campus, 862,000 master's and doctorate graduates, 36.594 million university and vocational college students, and 9.673 million graduates. Without a doubt, China has a massive local talent pool. According to data from the National Bureau of Statistics (NBS), in 2019, China sent 703,500 students abroad and received 583,000 students returning from overseas. Increasing international student exchange is conducive to global technology integration, productivity, innovation and application of technology, talent cultivation, and sustainable global development and inclusive growth.

This new form of national innovation system is expected to accelerate industrial innovation and market development. Typically, China's new energy vehicle (NEV) industry is prospering in its vast market space, which has the potential to transform the Western-dominated global automotive industry of the past century. According to data from the National Bureau of Statistics (NBS) and MIIT, the growth of China's NEV sales has outpaced the overall growth rate of the automotive industry. From 2014 to 2022, China's NEV production increased from 78,000 to 7,058,000 units, while sales volume increased from 75,000 to 6,887,000 units. China's NEV sales volume has ranked first in the world for eight consecutive years, according to data from the China Automotive Industry Association. China's NEV production and sales volume increased by 96.9% and 93.4% in 2022, respectively. China accounted for 58.7% of global sales of NEVs in 2022, surpassing Europe (25.5%) and North America (10.5%). NEVs and other emerging industries have facilitated the rapid expansion of China's midstream and upstream businesses, including Contemporary Amperex Technology Co., Limited.

5. Future of Innovation-Driven Development: Getting on a Fast Track

5.1 Cross-Industry Global Value Networks

Cross-industry global value networks enable more accessible and effective value integration for innovation-driven growth. As a result of globalization and digitalization, exchange and cooperation across industries and sectors become more convenient and efficient, transcending global geographical boundaries and facilitating a global layout in which regional comparative advantages are utilized to create value. Global value networks, which are led by multinational corporations, unite businesses and organizations from a vast array of industries and domains that collaborate to create value. Cross-industry global value networks enable businesses and organizations from various sectors and fields to

share resources and technologies for more efficient resource utilization, collaborate for the development and application of new technologies and products, and select optimal partners and suppliers around the world to reduce procurement and manufacturing costs. Cross-industry global value networks are a global partnership model rife with opportunities and challenges for businesses and organizations to establish effective partnerships and collaboration mechanisms for the transmission of cross-industry value creation on a global scale.

5.2 Big Data-Driven Products and User Experience-Based Design

As essential concepts for contemporary digital product design and development, big data-driven products and user experience-based design provide a brand-new source of innovation for innovation-driven development. The development of big data-driven products is founded on the analysis of data from multiple sources to identify opportunities for product optimization and improvement. By analyzing user search logs and behavioral data, for example, manufacturers can identify user needs, interests, and preferences to improve product quality and user experience. User experience-based design entails putting the user's requirements and experience at the center of product design and development in order to design more user-friendly products based on a demand survey and analysis. This design strategy prioritizes user experience and satisfaction in addition to product functionality and usability. Leading e-commerce websites such as Taobao and JD.com have designed more intuitive and user-friendly purchasing procedures and interfaces to improve user satisfaction and shopping experience. Data analysis and mining technologies can be used to obtain a more in-depth understanding of user needs and preferences and to provide more accurate and effective preferences for user experience-based design. In addition, user experience-based design can increase user satisfaction and loyalty, which reinforces data collection and analysis in a positive cycle.

5.3 Increasing Global M&As

Increasing global mergers and acquisitions (M&As) have resulted in a flexible deployment of global innovation resources in accordance with the innovation-driven development strategy. In the face of intensifying global competition, M&As provide a means for businesses to expand and become more efficient. There has been an increase in the number and volume of business mergers and acquisitions on a global scale. Given the saturation of certain markets, the only way to discover new growth opportunities and market demand is through M&As. With the development and opening of global capital markets, businesses have easier access to capital support for financing mergers and acquisitions. In some industries, intense competition has compelled businesses to consolidate and optimize resource distribution through mergers and acquisitions, which helps them maintain their business position and competitiveness. M&As allow businesses to acquire strategic assets, new technologies, and patents to enhance their innovative and technological capabilities. Geely's acquisition of Volvo, for example, enabled Geely to ascend from industry latecomer to global leader in passenger vehicles.

5.4 More Innovation Service Ecosystem Platforms

More innovation service ecosystems provide innovation-driven growth with diverse value propositions. With the evolution of digital and internet technologies from Web1.0 to Web2.0 and Web 3.0, innovation service ecosystem platforms have gained an increasing interest from businesses and consumers. Innovation service ecosystem platforms deliver innovative services and solutions to businesses and consumers using internet technologies and digital tools. To ensure the success and efficacy of innovation service ecosystem platforms, businesses should also be aware of the risks and difficulties associated with innovation ecosystem platforms, including technical and market risks. Xiaomi, for example, has successfully evaded the path dependence of traditional technical paradigms for home appliances, transforming into a global mobile internet technology company specializing in the

smart home ecosystem.

5.5 Manufacturing-Service Integration

Manufacturing-service integration serves as a high value-added business model for innovation-driven development. Manufacturing-service integration allows more individualized, efficient and smart products and services to be offered to consumers by integrating traditional manufacturing with services via digital and smart technologies. Amid changing consumer needs and consumption upgrade, there has been an increasing demand for individualized, high-quality and efficient products and services. That is why smarter and customized solutions should be provided through manufacturing-service integration. Digital and smart technologies have blurred the boundary between manufacturing and services, enabling manufacturing-service integration for more intelligent and efficient operations. In some traditional manufacturing sectors, in particular, traditional manufacturing modes may no longer meet market demand. Manufacturing needs service integration to realize industrial transition and upgrade. The government may issue policy documents to support manufacturing digital transition and service innovations to promote manufacturing-service integration.

5.6 Emerging Technologies and Unpredictable Future

Emerging technologies and an uncertain future open a window of strategic opportunities for an innovation-driven paradigm shift. Emerging technologies such asABCDE have fostered the growth of ever-expanding markets. Faced with the commercialization of R&D results as well as the risks and unpredictability of privacy and network security, businesses must persistently increase innovation and adaptability to deal with future changes and challenges. Frist, Businesses should prioritize innovation and implement new technologies and ideas to remain competitive. Second, ABCDE technologies necessitate that businesses strengthen their collaborative innovation partnerships to jointly face market changes and challenges. Leading businesses should broaden the purview of their cooperation and seek out suitable partners for the joint development of new products and services to share resources and data and enhance their innovativeness and competitiveness. Finally, ABCDE technologies have imposed greater demands on talent cultivation and development, necessitating effective management mechanisms to recruit and retain qualified professionals. Businesses place a premium on staff training and development to enhance employees' specialized skills and inventiveness, which in turn supports business development.

References:

[1] Bongiorni, S. 2007. *A Year Without "Made in China": One Family's True Life Adventure in the Global Economy*. Hoboken, New Jersey: John Wiley & Sons, Inc.

[2] Dosi, G. 1982. "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change." *Research Policy*, 11(3): 147-162.

[3] Hobday, M. 1995. *Innovation in East Asia: The Challenge to Japan*. Aldershot: Edward Elgar.

[4] Kerr, R.A. 2005. "How Hot Will the Greenhouse World Be?" *Science*, 309(5731): 100.

[5] Kim, L. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Cambridge, Mass: Harvard Business School Press.

[6] Lee, K., and C. Lim. 2001. "Technological Regimes, Catching-up and Leapfrogging: Findings from the Korean Industries. " *Research Policy*, 30(3): 459-483.

[7] Lin, Justin Yifu. 2019. "An Interpretation of China's Economic Development Miracle since the Founding of People's Republic of China." *Scientific Socialism*, 189(03):4-8.

[8] Utterback, J. M., and W. J. Abernathy. 1975. “A Dynamic Model of Process and Product Innovation. ” *Omega*, 3(6): 639-656.

[9] Wu, Dong, and Xiaobo Wu. 2013. “Technological Catching-up: China’s Content and Its Implications.” *Studies in Dialectics of Nature*, 29(11): 45-50.

[10] Wu, Dong. 2015. “A New Growth Paradigm for Manufacturing under Industry 4.0.” *PKU Business Review*, 133(08):92-97+22.

[11] Wu, X. B., J. P. Murmann, C. Huang, and B. Guo. 2020. *The Management Transformation of Huawei: From Humble Beginnings to Global Leadership.* Cambridge: Cambridge University Press.

[12] Wu, Xiaobo, and Dong Wu. 2018. “The Technology Innovation and Development of Chinese Firms.” *Studies in Science of Science*, 36(12): 2141-2143+2147.

[13] Wu, Xiaobo, Yanan Fu, Dong Wu, and Linan Lei. “How Do Latecomers Transform from Catch-up to Beyond Catch-up? A Longitudinal Comparative Analysis of Two Cases Based on Window of Opportunity Perspective.” *Journal of Management World*, 35(2): 151-167+200.

[14] Wu, Xiaobo. 1995. “The Evolutionary Process of the Secondary Innovation.” *Scientific Management*, 2:27-35.

[15] Xu, Qingrui, Xiaobo Wu, Jin Chen, and Dong Wu. 2019. *Made in China: Research on Innovation Strategy and Governance Structure beyond Catch-up.* Beijing: Science Press.