Analysis of China's Medium Technology Status (Post-print)

Authors: Lai Ge, Meng Bo

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Abstract

After years of development, the enhancement of China's manufacturing capabilities is widely recognized, yet it has not overcome the predicament of being "large but not strong, comprehensive but not excellent," a phenomenon that has attracted extensive attention from academic and policy circles. This article argues that technological progress is the core of high-quality manufacturing development, and through empirical research finds that in the early stages of economic development, latecomer countries can relatively easily achieve economic growth and thereby promote income enhancement through technological imitation; however, after technological imitation, achieving technological catch-up and original technological progress is by no means easy. Based on this fact, the article contends that China is currently at a medium technology level characterized by "ambushes ahead" (technological blockade from advanced countries) and "pursuing troops behind" (low-price competition pressure from other latecomer countries); only by vigorously promoting original technological progress can China avoid falling into the "medium technology trap."

Full Text

Preamble

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Empirical Analysis for China's Middle-Technology Status

LAI Ge[1]*, MENG Bo[2]

[1] Institute for International Affairs, Qianhai, The Chinese University of Hong Kong, Shenzhen, Shenzhen 518172, China
[2] Institute of Developing Economies, Japan External Trade Organization, Chiba 261-8545, Japan

Abstract

After years of development, China's manufacturing strength has improved markedly, yet it remains trapped in a situation of being "large but not strong, comprehensive but not excellent." This phenomenon has attracted widespread attention in academic and policy circles. This paper argues that technological progress is the core of high-quality manufacturing development. Through empirical research, we find that while latecomer economies can relatively easily achieve economic growth and income improvement through technology imitation in the early stages of development, transitioning from imitation to technological catch-up and original innovation proves exceedingly difficult. Based on this reality, we contend that China currently occupies a medium technology level, facing "ambushes from the front" (technological blockades from advanced countries) and "pursuers from behind" (low-cost competition from other latecomers). Only by vigorously promoting original technological progress can China avoid falling into the "middle-technology trap."

Keywords: middle-technology trap, China, high-quality development, technological progress

1. Problem Formulation and Debate: The Technological Factor Behind China's High-Quality Development

Classic literature and economic history have demonstrated that technological innovation is the primary driver of economic growth and industrial development. Solow[1] proposed the "Solow Model," identifying technological progress as the decisive factor in economic growth. Arrow[2] explained the role of technological innovation in driving economic growth from an endogenous technology perspective. Scholars have also understood technological progress from a catch-up perspective. Ohno[3], for instance, divides the industrialization catch-up of latecomer economies into four stages, with the technological hurdle occurring between stages 2 and 3—latecomer economies struggle to transition from technology absorption to technological innovation, causing their manufacturing upgrading to hit a "glass ceiling" [Figure 1: see original paper]. Kharas and Kohli[4] argue that countries stuck in middle-income status typically face a "squeeze from both ends," experiencing dual pressure: low-price competition from low-income country manufacturing and monopolistic effects based on technological innovation from high-income countries' high-tech sectors. Breaking this deadlock requires shifting the growth model from factor-driven to innovation-driven. Cowen[5] analogizes applied technological innovation to "low-hanging fruit," warning that if all such fruit has been picked and revolutionary technological innovation stagnates, economic decline becomes likely. Petralia et al.[6] emphasize that climbing the economic development ladder requires climbing the technological development ladder, as an economy's position in the global industrial division system largely depends on its technological capability level.

Zhang Xiazhun[7] examines theoretical myths about economic development in lagging regions, proposing the concepts of "rich country trap" and "kicking away the ladder." The "rich country trap" refers to how the UK and US, when still developing countries themselves, achieved capital and technology accumulation through trade protection policies such as infant industry protection and export subsidies; yet upon reaching developed status, they vigorously promoted free market economic systems as the "ladder" for technological leapfrogging and economic development, when in fact this is a "trap"—the real "ladder" is not free market economics but "big market, small government."

Chinese scholars have long recognized this issue. Cai Fang[8] proposed the "comparative advantage vacuum theory" to explain the awkward situation facing medium-technology countries: advanced countries, positioned at the frontier of technological innovation with significant comparative advantages in capital- and technology-intensive industries, reap substantial benefits from globalization; low-income countries, with abundant cheap labor, hold comparative advantages in labor-intensive industries and similarly benefit from globalization. However, countries at the middle-income stage, lacking prominence in either type of comparative advantage, gain less from globalization or even suffer losses. Similarly, Wang and Wei[9] constructed a "sandwich model" to further elaborate theoretically on the "ambush from the front, pursuit from behind" predicament facing middle-income countries: high-income countries with innovation advantages exert suppression effects on medium-income countries, while low-income countries with labor cost advantages exert chase effects, forcing middle-income countries to guard against both fronts while actively implementing industrial upgrading and improving independent innovation capabilities.

Thus, original technological progress is one of the core drivers of sustainable economic growth and steady income improvement—a point of consensus in academic and policy circles. Below, we empirically demonstrate China's current technological level and explore the concept of the "middle-technology trap."

2. Characteristic Facts of China's Current Middle-Technology Status

Since the reform and opening-up, particularly after joining the World Trade Organization (WTO) in 2001, Chinese enterprises have actively integrated into global value chains by leveraging labor cost advantages and policy incentives, making "world's factory," "Made in China," and even "Created in China" well-known descriptors[10]. In absolute terms, China's manufacturing value-added accounted for 29.79% of the global total in 2021, approaching the combined total of the United States, Japan, Germany, South Korea, and India (30.82%). However, compared with world-class manufacturing powers, China remains large but not strong. According to the Manufacturing Power Development Index released by the Chinese Academy of Engineering[11], China's manufacturing technology intensity still ranks in the third tier, with the risk of being constrained to the low- and medium-end by first- and second-tier countries like the US, Germany, and Japan .

The China Academy of Information and Communications Technology's *China Industrial Economic Outlook (2020)*[12] points out that although China has maintained its position as the world's largest industrial nation since 2010 with continuously optimizing industrial structure, it remains constrained by others in key core technologies. The foreign dependence ratio exceeds 50% in core basic components, key basic materials, basic technology, and industries; import dependency stands at 80% for integrated circuits, 90% for large high-quality castings and forgings, and nearly 100% for high-end hydraulic components and seals.

Similarly, taking the well-known Apple phone as an example, although China participates in processing and assembly and is incorporated into Apple's global value chain production network, the value-added gains are actually minimal, accounting for only 2.3% of total production value-added[13]. Xing et al.[14] further decompose intangible asset trade in Apple's iPhone X, including branding, operating systems, product design, and marketing activities, arguing that this intangible trade is not captured in traditional trade statistics, thus the US-China trade deficit is overestimated. Therefore, beyond processing and assembly, China's participation in other parts of the value chain—including upstream R&D, design, and key component manufacturing, and downstream marketing, branding, and customer service—needs improvement. This would complement China's strong manufacturing capabilities and enhance labor productivity and value-added.

2.1 R&D Investment and Patent Applications

The dimension of technological innovation input and output can measure the overall trend of China's technological innovation development: the greater a country's technological innovation input (such as R&D funding) and the more innovation output (such as patent quantity), the stronger its technological capability.

2.1.1 R&D Investment According to 2018 data from the Organisation for Economic Co-operation and Development (OECD), China ($465.287 billion) ranks second in R&D investment scale, still behind the United States ($618.066 billion) but significantly ahead of Japan ($172.036 billion), Germany ($142.320 billion), and South Korea ($100.283 billion) [Figure 2a: see original paper]. This shows that technological innovation has become the core of strategic competition among major powers, with the US firmly maintaining first place and keeping a large gap with other countries. However, in terms of the gap with the US, China is undoubtedly the closest pursuer—one important reason why the US defines China as a strategic competitor. In terms of R&D intensity, China (2.14%) ranks 16th, slightly below the OECD average (2.49%) and behind the US, Israel, South Korea, Taiwan, Japan, and major European economies [Figure 2b: see original paper]. This reflects that while China's absolute technological innovation input ranks among the top, its input intensity still lags behind first-tier technological powers. From a time series perspective, between 1981 and 2021, particularly since the 21st century, both China and the US have seen rapid R&D expenditure growth [Figure 3: see original paper]. The US advantage remains significant and far ahead, while China has caught up vigorously, surpassing Germany in 2005 and Japan in 2008 to become the world's second-largest R&D spender, with the gap with the US narrowing daily. Meanwhile, the gap between Germany and Japan and the first-tier US and China continues to widen.

2.1.2 Innovation Output Taking OECD triadic patent families data as an example [Figure 4: see original paper], in 2019, Japan, the US, China, Germany, and South Korea ranked top five in triadic patent applications. Among them, China's patent applications numbered 5,893, accounting for 10.2% of the world total and ranking third globally, but far behind Japan (30.6%) and the US (22.6%), and only slightly ahead of Germany (7.5%) and South Korea (3.2%). This reflects China's gradual progress toward becoming a world science and technology power, but its technological innovation capability still lags behind the technological leadership of Japan and the US, leaving considerable room for catch-up.

From a time series perspective, the US and Japan stand at the forefront of world science and technology—the first tier [Figure 5: see original paper]. Since the 1990s, the US has consistently led the information technology revolution and achieved many original technological results. Japan caught up later, with its patent numbers showing rapid growth between 1985 and 2000, surpassing the US for the first time in 2000 to become world number one. Although it has remained ahead of the US since then, its growth has gradually weakened. China, since joining the WTO in 2001, has seen its technological innovation capability improve significantly, successively surpassing South Korea in 2014 and Germany in 2018 to become the second-largest patent applicant by quantity.

2.1.3 Technological Innovation Status of China's Manufacturing Compared with other industries, in 2021, China's computer, communications, and other electronic equipment manufacturing showed obvious advantages in both patent applications and R&D funding [Figure 6: see original paper], demonstrating characteristics of high-intensity technological innovation input and high-tech content output. The following industries are: electrical machinery and equipment; special-purpose equipment; general-purpose equipment;

automobiles; and transport equipment such as railways, ships, and aerospace. These industries also exhibit technology-intensive characteristics and serve as pillar industries for building a world science and technology power.

2.2 International Competitiveness of Export Products' Technological Innovation

In the era of globalization, economies or industries form an international trade division pattern through market self-exploration: countries with high technological advantages export relatively high-tech products, while labor-intensive countries export low-tech products. Here, we use three indices—the Economic Complexity Index (ECI), Domestic Value Added (DVA) in manufacturing exports by technology level, and Revealed Comparative Advantage based on DVA (RCA_{DVA})—to measure China's international competitiveness in technological innovation from an export product perspective. The higher a country's economic complexity, the higher the DVA share in its exports, or the more prominent its comparative advantage in medium- and high-tech manufacturing, the stronger its technological advantage.

2.2.1 Economic Complexity Index (ECI) The ECI, created by Harvard University's Growth Lab, specifically measures a country's comprehensive performance in industrial exports, including the diversity and complexity of export products[15]. Specifically, the higher a country's ECI, the higher its technological level.

[Figure 7: see original paper] shows the ECI ranking trends for China and selected economies: Japan consistently ranks first, followed closely by Germany, reflecting the technological strength of these two major manufacturing powers. South Korea's ranking continues to improve, demonstrating the strong competitiveness of its innovation system. Due to manufacturing hollowing-out, the US has fallen to the second tier, ranking 12th in 2020. China's ranking has risen year by year, climbing to 17th in 2020, also placing it in the second tier. India and Vietnam, as major destinations for low- and medium-end manufacturing transfer, ranked similarly in 2020 at 46th and 52nd, respectively.

2.2.2 Domestic Value Added (DVA) in Export Decomposition With the rise of intra-product division, developing countries participate in international division mainly by embedding in the low-end segments of global value chains through processing trade. DVA represents the actual value created by each economy in participating in global value chains, more accurately reflecting value-added gains. By comparing DVA in low-tech versus medium- and high-tech manufacturing, we can observe changes in technological advantages in international division.

If a country's DVA in medium- and high-tech manufacturing and its share steadily increase, this proves technological upgrading. Based on technology content, 16 manufacturing sectors are divided into two categories: low-tech manufacturing (9 sectors) and medium- and high-tech manufacturing (7 sectors). In absolute terms, DVA in medium- and high-tech manufacturing is significantly higher than in low-tech manufacturing, and its growth over time is much larger, proving that China is increasingly embedding in medium- and high-tech manufacturing in global value chain division [Figure 8: see original paper]. Examining the trend of DVA as a proportion of exports, the DVA share in low-tech manufacturing fluctuates around 40%, while that in medium- and high-tech manufacturing fluctuates around 55%, further indicating China's stronger ability to capture gains in medium- and high-tech manufacturing.

2.2.3 Revealed Comparative Advantage Based on DVA (RCA_{DVA})

The RCA index, proposed in 1965, measures whether a country's product or industry has comparative advantage in international market competition through customs trade statistics. The RCA_{DVA} index improves upon the RCA index by using the "value-added trade" statistical method. Based on domestic value added in final products rather than final products themselves, RCA_{DVA} more accurately reflects a country's actual export competitiveness[16].

Like RCA, when RCA_{DVA} > 1, the sector's exports have revealed comparative advantage; when RCA_{DVA} 1, export competitiveness is neutral; and when RCA_{DVA} < 1, the sector has revealed comparative disadvantage.

(1) China's RCA_{DVA} Trends. As shown in [Figure 9: see original paper], during 2000–2021, China's RCA_{DVA} in medium- and high-tech manufacturing increased year by year, while that in low-tech manufacturing declined gradually. In recent years, both have converged around 1.4 (both >1). This reflects China's strength as a manufacturing powerhouse: it possesses international competitiveness in both medium- and high-tech and low-tech manufacturing. In terms of trends, low-tech manufacturing RCA_{DVA} gradually declined from 1.85 in 2000 to 1.4 in 2021, indicating that while China still holds international competitiveness in low-tech manufacturing, this advantage is significantly diminishing as technological innovation capability improves. Conversely, medium- and high-tech manufacturing RCA_{DVA} steadily increased from 0.9 in 2000 to 1.4 in 2021, confirming the rise of China's medium- and high-tech manufacturing.

(2) RCA_{DVA} Rankings by Economy in Total Industries. To further illustrate China's manufacturing international competitiveness, we rank 63 economies covered in the ADB input-output tables based on RCA_{DVA} in low-tech and medium- and high-tech manufacturing [Figure 10: see original paper]. Notably, China's ranking in low-tech manufacturing RCA_{DVA} shows a declining trend, from 14th in 2000 to 22nd in 2021. In medium- and high-tech manufacturing, however, it shows a significant upward trend, rising from 23rd in 2000 to 4th in 2021, behind only Taiwan, Japan, and South Korea.

(3) RCA_{DVA} Rankings by Economy in Three Technology-

Intensive Industries. We further examine three representative medium- and high-tech manufacturing sectors—machinery manufacturing, electronics and optical manufacturing, and transport equipment manufacturing—ranking economies by RCA_{DVA} . Overall, China's comparative advantage in these three technology-intensive manufacturing sectors is not top-tier but upper-middle or middle. China shows considerable comparative advantage in electronics and optical manufacturing (1.54), ranking 6th; some advantage in machinery manufacturing (1.24), ranking 12th; but performs poorly in transport equipment manufacturing (0.57), ranking 25th.

2.3 Position in Global Value Chains

To further assess China's position in the global manufacturing gradient pattern, this section measures China's manufacturing technological content from a global value chain perspective, using two key indicators: global value chain participation and global value chain position index.

2.3.1 Global Value Chain Participation Global value chain participation can be divided into forward and backward participation. Forward participation refers to joining global division through exporting intermediate goods, while backward participation refers to joining through importing intermediate goods. In most periods, China's backward participation exceeds forward participation [Figure 11: see original paper], indicating that China's manufacturing generally occupies midstream and downstream positions in value chains, still undertaking production tasks with low technological content such as processing and assembly. Notably, vertically, the gap between backward and forward participation is gradually narrowing: backward participation has entered a long-term downward channel, while forward participation has steadily increased. Relying on an increasingly mature domestic manufacturing production system, China's industrial chain has become more complete, and its role in global value chains has transformed: gradually upgrading from a downstream intermediate goods assembly base to a midstream and upstream intermediate goods supplier, reflecting improved technological levels.

2.3.2 Global Value Chain Position Index The global value chain position index further measures a sector's physical position in global value chains. The core of a country's manufacturing global value chain upgrading lies in its production division status—that is, its global value chain position: excluding some energy and mining industries, the higher the upstreamness, the higher a country's manufacturing technological content.

Excluding minerals and energy, most of China's manufacturing sectors are located in midstream and downstream positions; technology-intensive manufacturing such as transport equipment, electronics and optical manufacturing, and machinery manufacturing all occupy relatively downstream positions [Figure 12: see original paper]. This means China's manufacturing currently remains in the downstream segments of global value chains, with the phenomenon of intermediate goods processing trade dominance not fundamentally changed: upstream, it relies on raw material inputs from resource-exporting countries and imports of high-tech intermediate goods such as high-end equipment, intellectual property, and key components.

Additionally, most Chinese manufacturing sectors have $RCA_{DVA} > 1$, indicating revealed comparative advantage in international trade and reflecting the overall comprehensive strength of China's manufacturing. However, further distinguishing between low-tech and medium- and high-tech manufacturing reveals that low-tech manufacturing shows more prominent revealed comparative advantage, such as leather and footwear, textiles, and other manufacturing. Relatively, except for other non-metallic mineral products, medium- and high-tech manufacturing shows less significant comparative advantage, particularly transport equipment manufacturing, which shows obvious disadvantage.

3. Middle-Technology Status and the "Middle-Technology Trap"

3.1 China's Manufacturing Overall Remains at Medium Technology Level

Although China has made significant technological progress over time and achieved technological catch-up in some industries, its manufacturing as a whole remains at a medium technology level, lagging behind first- and second-tier technological powers such as the US, Japan, and Germany. How to measure and define medium technology has not yet reached a unified consensus in academia. This paper comprehensively assesses China's position in the global manufacturing gradient pattern from three dimensions: technological innovation input and output, international competitiveness of export products' technological innovation, and global value chains, pointing out significant technological gaps with top-tier technological powers.

The "medium technology" discussed in this paper does not refer to zero absolute technological progress speed—technology is always changing and advancing, and data show that latecomer manufacturing powers have made remarkable technological progress. Rather, it is a concept of relative speed: that is, the technological gap between latecomer (medium-technology) economies and advanced economies is difficult to narrow. As Zheng Yongnian[17] points out, "medium technology" refers to the comparison of technological levels between one country and another or group of countries. For example, in manufacturing, the US occupies the first tier, Europe and Japan the second tier, and China the third tier. It is undeniable that from a data perspective, latecomer manufacturing powers have made obvious technological progress, but overall, the technology gap with advanced countries remains significant.

3.2 The "Middle-Technology Trap" Is a Structural Dilemma

From the perspective of technological catch-up by latecomers, after experiencing technology introduction, imitation, absorption, and tracking, latecomer countries face a steady state where insufficient original technological progress makes industrial upgrading difficult and convergence with high-income countries unattainable. We summarize this as the "middle-technology trap."

According to this relative speed concept, ample cases in relevant academic and policy research demonstrate the existence of this non-convergent growth phenomenon. The "middle-technology trap" is not an isolated case but a structural situation that latecomer countries collectively face after reaching a certain development level. Without achieving original technological progress to become first-tier technological powers, medium-technology economies will on the one hand encounter decoupling and supply chain disruptions from high-tech sectors of developed countries, making it difficult to obtain technology spillovers from advanced nations; on the other hand, with rising labor costs, tightening resource and environmental constraints, and trade frictions initiated by developed economies, they also face a "low-end diversion" trend from other developing economies with even lower cost advantages, making existing comparative advantages and participation patterns in global value chains unsustainable. Therefore, how to cross the "middle-technology trap" through original technological progress is one of the most important issues China currently faces.

References

1. Solow R M. Technical change and the aggregate production function. *The Review of Economics and Statistics*, 1957, 39(3): 312-320.

2. Arrow K J. Economic welfare and the allocation of resources for invention// The Rate and Direction of Inventive Activity. Princeton: Princeton University Press, 1962: 609-626.

3. Ohno K. Avoiding the middle-income trap: Renovating industrial policy formulation in Vietnam. *ASEAN Economic Bulletin*, 2009, 26(1): 25-43.

4. Kharas H, Kohli H. What is the middle-income trap, why do countries fall into it, and how can it be avoided?. *Global Journal of Emerging Market Economies*, 2011, 3(3): 281-289.

5. Cowen T. *The Great Stagnation—The Economic Malaise at a Plateau: Problems of the United States and Opportunities for China.* Translated by Wang Y. Shanghai: Shanghai People's Publishing House, 2015.

6. Petralia S, Balland P A, Morrison A. Climbing the ladder of technological development. *Research Policy*, 2017, 46(5): 956-969.

7. Chang H J. *Kicking Away the Ladder: Development Strategy in Historical Perspective.* Translated by Cai J. Beijing: Social Sciences Academic Press (China), 2020.

8. Cai F. Theory, experience and pertinence of "middle-income trap". *Economic Perspectives*, 2011, (12): 4-9.
9. Wang Y, Wei S J. Sandwich effect: Challenges for middle-income countries. (2019-06-06)[2023-08-01]. https://www.nber.org/conferences/east-asian-seminar-economics-2019.
10. Chinese Academy of Engineering. *China's Manufacturing Development Index for 2021*. Beijing: Chinese Academy of Engineering, 2022.
11. China Academy of Information and Communications Technology (CAICT). *China's Industrial Economic Outlook (2020)*. Beijing: China Academy of Information and Communications Technology, 2020.
12. Xing Y, Detert N. How the iPhone widens the US trade deficit with China: The case of the iPhone. *PCER Working Paper*, 2010.
13. Xing Y, Dollar D, Meng B. Trade in intangible assets along global value chains and intellectual property protection// Xing Y, Gentile E, Dollar D, eds. *Global Value Chain Development Report 2021: Beyond Production*. Mandaluyong City: Asian Development Bank, 2022: 43-71.
14. Zheng Y N. How can China avoid the middle-technology trap?. *Bulletin of Chinese Academy of Sciences*, 2023, 38(11): 1579-1592.
15. Harvard University Growth Lab. https://atlas.cid.harvard.edu/glossary
16. OECD. https://www.oecd-ilibrary.org/science-and-technology/data/oecd-patent-statistics_{patent}-data-en
17. Zheng Yongnian. Research on China's strategy for crossing the "middle-technology trap". *Bulletin of Chinese Academy of Sciences*, 2023, 38(11): 1579-1592.

Note: Figure translations are in progress. See original paper for figures.