



Upgrading of Chinese Domestic Firms in Advanced Manufacturing: Evidence from Industrial Robots and High-Tech Medical Devices

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1 INTRODUCTION

The global value chain (GVC) perspective looks at global industries from two angles: top down and bottom up (Gereffi and Fernandez-Stark 2016). The top-down view is about the governance of GVCs, which examines the organizations and relationships between GVC lead firms and other GVC participants, with various structures including captive, relational, modular, market, and hierarchy types (Gereffi et al. 2005). The bottom-up view is about upgrading along GVCs, which highlights the strategies used by countries and firms to improve their positions from low- to high-value-added activities in the global economy (Gereffi 2014).

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For developing countries, the bottom-up angle is more relevant. After entering into GVCs, developing economies have utilized diverse strategies to climb up the value chains and reap more benefits from their participation.

Since China's reform and opening up was introduced in 1978, the country has played an increasingly important role in GVCs and became the world's factory. Initially, to integrate into GVCs, Chinese domestic firms undertook and specialized in certain low-value-added tasks (e.g., processing and assembly). Nevertheless, they managed to upgrade over time and China has become a supply hub in the GVCs of most sectors (WTO et al. 2019). Recently, the rapid development in digitalization and innovation around the world has brought new challenges and opportunities to China's upgrading path. China has launched several national plans focusing on advanced manufacturing which is mostly digitally powered and relies on advanced technologies. For example, China launched "Made in China 2025" that targeted 10 key industries. In the recent 14th Five-Year Plan (2021–2025), China also emphasized the development of advanced manufacturing.

Against this backdrop, it is particularly important to analyze the upgrading of Chinese domestic firms in advanced manufacturing since these may require more specialized tools compared to the upgrading path of other sectors. Based on diverse qualitative and quantitative evidence from two sectors, industrial robots and high-tech medical devices, which were included in both "Made in China 2025" and the 14th Five-Year Plan, this chapter will identify the upgrading trends of Chinese domestic firms, discuss the driving forces behind these trends, and provide a detailed look at national and local policies supporting these upgrading efforts. Although moving up in advanced manufacturing GVCs is China's national policy priority, little empirical research is available in the literature that analyzes the success of this initiative in specific industries and focusing on firm-level characteristics, including ownership and market orientation. This chapter will fill this gap to some extent and thus contribute to the ongoing discussions of GVC upgrading in China's advanced manufacturing sectors.

The chapter is structured as follows. Section 2 provides a brief overview of the literature on GVC upgrading, with a focus on industrial robots and high-tech medical devices from a GVC perspective. Section 3 discusses the data and methodology used in this analysis. Section 4 analyzes our empirical findings for the industrial robot and high-tech medical device

GVCs in China, showing the upgrading trends of Chinese firms in these two sectors. Section 5 discusses the driving forces behind these upgrading trajectories in the past and factors that will likely affect upgrading in the future, including internal and external factors. Section 6 concludes with policy implications of our analysis for China's future upgrading in advanced manufacturing GVCs.

2 LITERATURE REVIEW

GVC upgrading is a bottom-up view of moving from low-value to high-value activities in global production networks (Gereffi 2014, 2019). Various typologies of GVC upgrading have been proposed in the last two decades. For example, one of the most widely used typologies includes four types of GVC upgrading, namely, product, process, functional and chain upgrading (Humphrey and Schmitz 2002). The drivers of upgrading are also studied, including building export capabilities, leveraging services to enhance knowledge capabilities, fostering public-private partnerships to narrow the human capital gap, knowledge spillovers from foreign direct investment (FDI) and GVC lead firms, the role of industrial clusters, and the interactions between manufacturing and services activities, among others (Gereffi 2015; Gereffi and Lee 2016; Gereffi et al. 2019).

However, there has been little empirical research on GVC upgrading paths and drivers of Chinese domestic firms in advanced manufacturing, particularly industrial robots and high-tech medical devices. A recent study analyzes the upgrading trajectory of the medical devices sector in Costa Rica and highlights the importance of foreign direct investment (FDI) and services (Gereffi et al. 2019). However, the findings may not apply to China's medical devices sector since Costa Rica is an FDI-led, export-oriented, small economy, while China relies on a mix of state-owned enterprises (SOEs), multinational enterprises (MNEs), and domestic firms for its export model and it has a very large domestic market that absorbs much of the economy's output. Meanwhile, another study describes the shift of China's medical device exports from low-tech goods to medium- and high-tech devices during 2001–2016 and considers the trend as a sign of China's upgrading in the medical device sector (Torsekar 2018). This analysis reflects only one side of upgrading, however, since China has large domestic demand for medical devices as well. Furthermore, without indicating the ownership structure of the exports, it is

uncertain if the trend is dominated by MNEs in China or driven by the upgrading of local medical device producers.

Export-led and domestic-market-led economies may have different upgrading paths (Brandt and Thun 2016). The large domestic markets create opportunities for local firms: the low end provides domestic firms with an “incubation space” which is free from competition with foreign giants and allows local firms to gain scale; and the higher end attracts foreign firms to invest and localize activities, and also incentivizes domestic firms to upgrade. Therefore, in China’s case, it is necessary to investigate the upgrading of local firms in the domestic market. In addition, although there have been various studies on impacts of industrial robots on employment and productivity in China, the US, and Europe (Cheng et al. 2019; Acemoglu and Restrepo 2020; Acemoglu et al. 2020), little evidence has been provided about the upgrading of the industrial robot sector itself.

In this chapter, the GVC perspective is used to analyze the upgrading trajectories of domestic firms in both the industrial robot and high-tech medical device GVCs in China. Upgrading in the global market (e.g., ownership structure of exports) and upgrading in the domestic market are both investigated. We not only analyze the market segments (global vs. domestic) and production stages (upstream, midstream and downstream) from a GVC angle, but also review China’s local policies in the GVC context. We provide various empirical findings to support our analysis.

3 METHODOLOGY

We use a mix of quantitative and qualitative materials in the analysis. Given that quantitative and qualitative approaches both have their strengths and weaknesses, we combine them to provide a general picture of upgrading of Chinese firms.

First, we use China’s Customs dataset to describe the exports by firm ownership in the two sectors, i.e., industrial robots and high-tech medical devices. The export dataset includes HS 6-digit product codes, production cities in China, ownership of exporting firms, export values, export quantities, and destination economies for 2001–2017. By using the HS 6-digit code, we can identify specific products within the industrial robot and high-tech medical device sectors (e.g., CT and MRI). The information on firm ownership as well as destinations allow us to calculate the export shares of different types of firms (e.g., Chinese

SOEs, Chinese private firms and foreign firms) in China's exports to the advanced economies (e.g., the US and Europe). Then we can describe the international competitiveness of Chinese domestic firms.

Second, we use statistics from various Chinese websites and industrial reports to describe the domestic market share by firm ownership in the Chinese market for the two sectors. For example, we provide the market shares of major suppliers of key components of industrial robots (e.g., gear reducer and servo system) and robot bodies in the Chinese domestic market. We also review top manufacturers in the domestic high-tech medical devices market (i.e., CT and MRI markets). Thus, we can analyze the domestic competitiveness of Chinese-owned firms. Additionally, we provide selected firm case studies for the two sectors from publicly available sources.

Finally, we have collected detailed Chinese policy information regarding the two sectors from various Chinese websites, mostly official government websites. Since these two sectors were included in the national plan "Made in China 2025" in 2015, and their upgrading prior to 2015 was mostly driven by economic (demand-pull) factors, rather than policy (supply-push) factors, we focus on the period of 2015–2021 for our policy review. It includes national policies by the central government (i.e., State Council and Ministries) as well as local policies by provincial and municipal governments. For relevant policies, the key policy content (i.e., main targets or tasks) is summarized in the Appendix (Tables 1, 2, 3, 4). Detailed policy analysis helps us understand the policy determinants behind the upgrading patterns of Chinese firms.

4 A GVC UPGRADING ANALYSIS OF CHINESE DOMESTIC FIRMS IN ADVANCED MANUFACTURING

Industrial robots and high-tech medical devices are two examples of advanced manufacturing in China. They are both included in national plans, such as "Made in China 2025" and the more recent 14th Five-Year Plan (2021–2025). Upgrading in these two sectors is critical to China's efforts to boost industrial competitiveness, on the one hand, and to cope with issues related to the rapidly aging population, on the other. Meanwhile, these two sectors are also important to the Chinese economy because of their size and growth. According to the International Federation of Robotics (IFR), China has become the largest robot

adopter in the world since 2016 in terms of operational stocks of industrial robots (IFR Secretariat Blog 2018). During the pandemic, China greatly increased the usage of industrial robots. In 2020, 167,000 units of industrial robots were installed in China, a 19% increase compared to 2019, accounting for 44% of global robot installations in 2020 (IFR 2021). At the same time, China has the second largest medical devices market worldwide, with an annual growth rate of 20%, far outpacing the country's economic growth (Allen 2020). Additionally, the COVID-19 pandemic has increased the demand in these two sectors. The international competitiveness of Chinese domestic firms, competitiveness in the domestic market, value chain analyses, and firm case studies for these two sectors are discussed in the following sections.

4.1 Chinese Domestic Firms in the Industrial Robot GVC

4.1.1 Performance in the Global Market

China started to increase its exports of industrial robots after 2010, implying an expanded robot production within the country. However, China has been a large robot importer since its accession to the World Trade Organization (WTO) in 2001, and its imports of industrial robots have grown faster than its exports (Fig. 1). Thus, China has a significant trade deficit in industrial robots. Specifically, in 2020, China exported US\$ 243 million worth of industrial robots, while importing US\$ 1042 million, a deficit of US\$ 800 million. This big gap suggests that China still relies on imports to meet the increasing needs of robot adoption within China, and its robot producers are not strongly and internationally competitive yet.

China's robot manufacturers consist of both Chinese domestic firms and MNEs that operate in the country, and the latter dominate Chinese exports of industrial robots after 2010, especially the exports to the advanced countries, for example, the US and European economies. Since robots exported to the advanced economies tend to be of higher quality, we focus on the firm ownership distribution of these exports, and find that during 2010–2017, on average, 86% of exports of industrial robots from China to the US and Europe were from foreign firms in China, rather than Chinese domestic suppliers (Fig. 2). In 2017, Chinese SOEs, Chinese domestic private firms and MNEs accounted for 1%, 10%, and 89%, respectively, of industrial robot exports to the US and Europe. The ownership structure of high-quality exports, together with the general

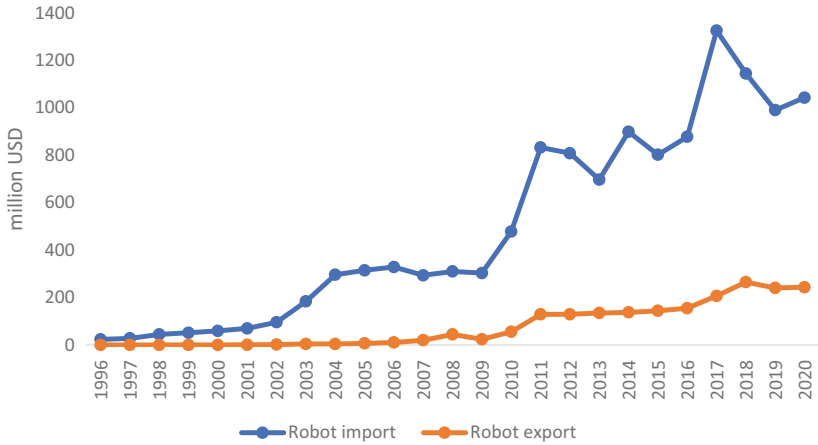


Fig. 1 China's imports and exports of industrial robots with the whole world
Note The HS 6-digit code for industrial robots is 847950
Source UNCOMTRADE database

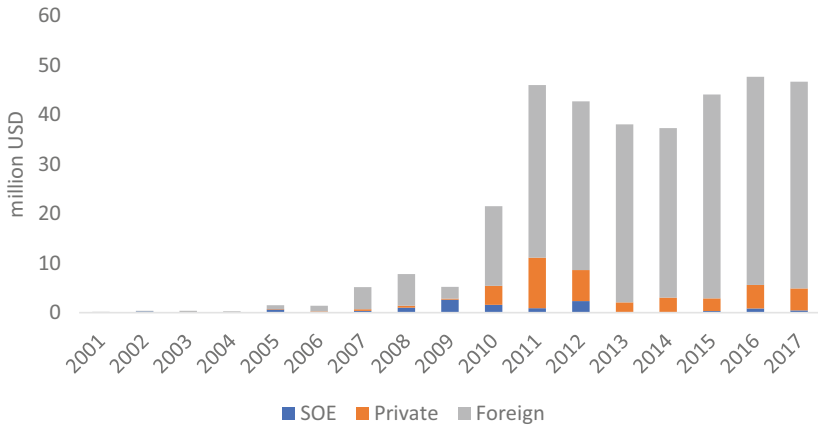


Fig. 2 China's exports of industrial robots to the US and Europe by exporters' ownership
Source China's customs data

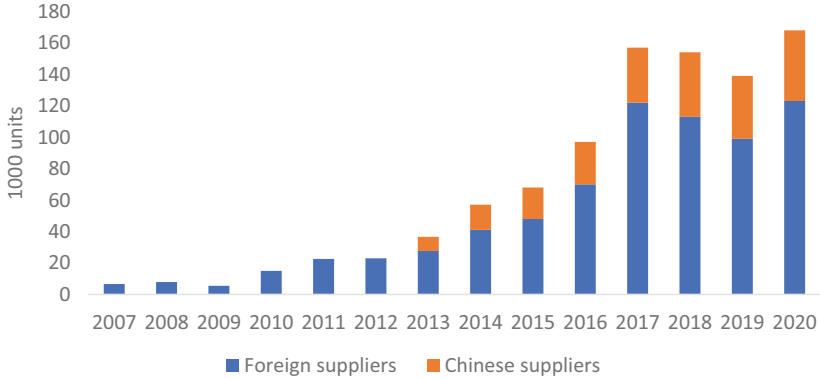


Fig. 3 Annual installation of industrial robots in China by supplier ownership
Source Pittman [2016], Wessling [2022]

trade deficit in industrial robots, indicates a relatively weak international competitiveness of Chinese domestic robot firms.

4.1.2 *Performance in the Chinese Domestic Market*

In the past, almost all the industrial robots installed in China were from foreign suppliers, i.e., either imported or made by MNEs in China. However, after 2013, domestic robot producers started to increase their participation in the domestic market (Fig. 3). The sales of domestic industrial robots increased from 9000 units in 2013 to 44,000 units in 2020, with an average yearly growth rate of 27%. In the meantime, the number of Chinese robot firms increased rapidly.

Nevertheless, in the domestic market of industrial robots, the market share of Chinese domestic firms is still much lower than that of foreign firms. In 2020, 26% of newly installed industrial robots in China were produced by Chinese domestic firms, while the remaining 74% were from foreign robot suppliers. This suggests that Chinese robot producers still need to keep improving their domestic competitiveness to gain market share.

4.1.3 *Upstream, Midstream, and Downstream Analyses*

The upstream of the industrial robots GVC comprises the production of key parts and components, including robot gear reducers, robot

controllers, and robot servo systems. These three key inputs account for almost 70% of production costs of industrial robots, and most of them are made by foreign firms, rather than Chinese domestic firms. Specifically, for robot gear reducers, the Chinese market is dominated by Japanese firms, with Nabtesco Corporation (Japan) as the biggest supplier, accounting for 60% of robot gear reducer supplies in China. For robot controllers, the top five suppliers in the Chinese market are FANUC (Japan), KUKA (Germany), ABB (Switzerland), Yaskawa Electric Corporation (Japan), and Epson (Japan), together accounting for 60% of the Chinese market. For robot servo systems, the top five suppliers in the Chinese market are Yaskawa Electric Corporation (Japan), Panasonic (Japan), Mitsubishi (Japan), Delta Electronics (Taiwan, China), and Siemens (Germany), capturing 58% of the Chinese market (Fig. 4). While there are also some Chinese domestic suppliers, their domestic market share is only about 15%.

The midstream of the industrial robot GVC is the production of robot bodies, including linear robots, articulated robots, SCARA robots, cylindrical robots, and other types, accounting for almost 25% of robot

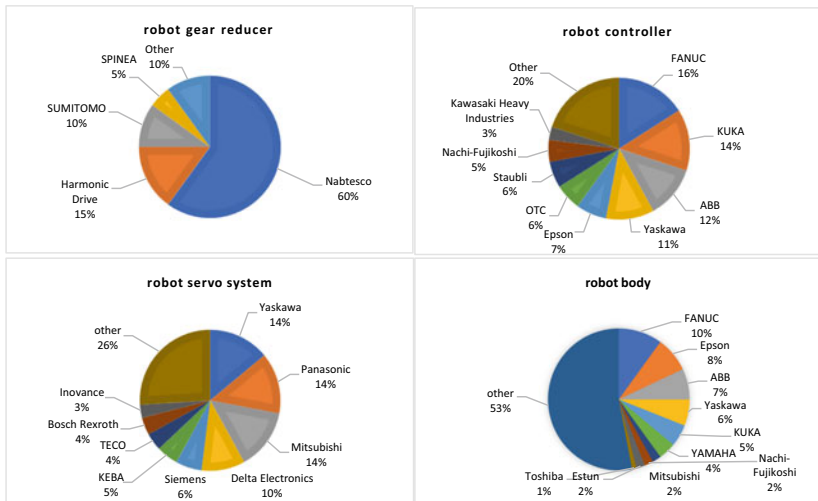


Fig. 4 Major suppliers of key components and robot bodies in the Chinese market of industrial robots

Source Wei [2019], Qianzhan Industry Research Institute [2021]

production costs. Compared to the key components, the costs of robot-body manufacturing, as well as the technology requirements, are relatively lower. Yet, the majority of the Chinese market is still occupied by foreign firms. Specifically, around 70% of robot bodies are provided by foreign firms. In 2020, among the top 10 robot-body producers in the Chinese market, only one of them was a domestic producer, i.e., Estun Automation Co. Ltd. (hereinafter Estun), headquartered in Nanjing City (Fig. 4).

The downstream of industrial robots GVCs consists of robot system integration and industry applications. By the end of 2020, there were 11,066 robot firms in China (Qianzhan Industry Research Institute 2021). About 80% of them are robot system integrators and 95% of integrators are Chinese domestic firms, which are usually small and serve the medium- to low-end markets (Shi 2021). The industry distribution of robot installation in China is similar to that for the whole world, i.e., automotive, electronics, metal, chemicals, rubber and plastic products, and food industry are the top robot adopters (Cheng et al. 2019).

4.1.4 Firm Case Study: Estun

The above GVC analysis shows that most of the robot key components and robot bodies are produced by foreign firms, and the majority of the Chinese robot companies are robot system integrators, rather than robot producers. However, one exception is Estun, a leading domestic industrial robot manufacturer in China. Morgan Stanley (2019) listed Estun as one of 61 global leaders at the forefront of the “second machine age” transition, along with the global robot giants such as ABB, FANUC, and Yaskawa.

Estun was established in 1993 in Nanjing City as a manufacturer of control systems for metal-forming machinery. Through the 1990s, Estun developed its own portfolio of automation products that range from servo drives and servo motors to robots, and from motion controllers to “turnkey” smart manufacturing lines (Estun 2022). Estun soon became a leader in the domestic robot industry in China and was publicly listed in the Shenzhen Stock Exchange in 2015. Its revenue reached 2.49 billion RMB in 2020, a 58.9% increase compared to 2019, and its gross profit margin was 30.5% in 2020 (MarketWatch 2022a), which was comparable to that of ABB (30%) and FANUC (36%) (Craft 2022a, 2022b).

The successful transformation and upgrading of Estun is attributable to its firm strategies. First, Estun has adopted an “All Made by Estun”

strategy on its robot production line, aiming at building the whole value chain of core components, industrial robots, and robot intelligent system engineering within the firm. It makes 85% of key inputs by itself, and thus controls its cost competitiveness (Gaogong Robot 2020).

Second, Estun values research and development (R&D). In 2020, Estun invested 147 million RMB in R&D activities, a 25% increase compared to 2019, and its R&D intensity (R&D relative to revenue) was 5.9%, while the R&D intensity of ABB was 4.2% in 2020 (Market-Watch, 2022a, 2022b). Furthermore, Estun also implemented a number of overseas mergers and acquisition (M&A) transactions dedicated mainly to R&D. For example, in 2017, Estun acquired TRIO in the UK (motion controller), 20% of Euclid Labs in Italy (visionics for robots), and BARRETT in the US (exoskeleton drive system). In 2018, it also gained control of MAi in Germany (robotic production system) (Estun 2022). Through R&D and M&A, Estun has developed key technologies and integrated technical resources, which greatly contributed to the establishment of a more comprehensive within-firm value chain, including the production of key components with high technical requirements.

Third, and finally, Estun also has a strategic layout within China. For example, although Estun is headquartered in Nanjing City, part of the Yangtze River Delta (YRD), it made investments in Foshan City in 2021 and will establish an industrial base there, partnering with a leading European robot company, CLOOS (Foshan China 2021). Since Foshan City is located in the Pearl River Delta (PRD), as well as the Guangdong-Hong Kong-Macao Greater Bay Area (GBA), this strategic plan allows Estun to leverage the large manufacturing base and access the broad market in the PRD and GBA. Foshan City has also become one of China's centers for robot production. Additionally, various macro (non-firm-specific) factors push the upgrading process of Estun, including local policy support, large domestic demand and external factors. We will discuss them in detail in Sect. 5.

4.2 Chinese Domestic Firms in the High-Tech Medical Devices GVCs

4.2.1 Performance in the Global Market

Medical devices can be divided into four categories based on their technological sophistication, i.e., disposables, instruments, therapeutics, and capital equipment (Bamber and Gereffi 2013). Among these product categories, capital equipment can be referred to as high-tech medical

devices, which include complex, single-purchase machines that can be used repeatedly over years and need large and long-term investments, such as computed tomography (CT) scanners and magnetic resonance imaging (MRI) devices.

Since its 2001 accession to the WTO, China has increasingly exported capital equipment, with an average yearly growth rate of 19.8% over the period of 2002–2020 (Fig. 5). In 2020, China's exports of capital equipment reached US\$ 4679 million, accounting for 38% of total medical device exports. It is noteworthy that China has a significant and continuous trade deficit in capital equipment. However, the gap between imports and exports is narrowing in the recent years. During 2018–2020, China's exports of capital equipment grew much faster than imports. Specifically, the export growth rates were 12.4%, 9.5%, and 15.7% in 2018, 2019, and 2020, respectively, and the import growth rates were 11.6%, 2.8%, and 4.6%. The high export growth in 2020 was largely driven by the surging demand for medical equipment in the other countries due to the COVID-19 pandemic, as well as the interim relaxation of regulatory requirements on imported equipment in major economies (e.g., the US and Europe).

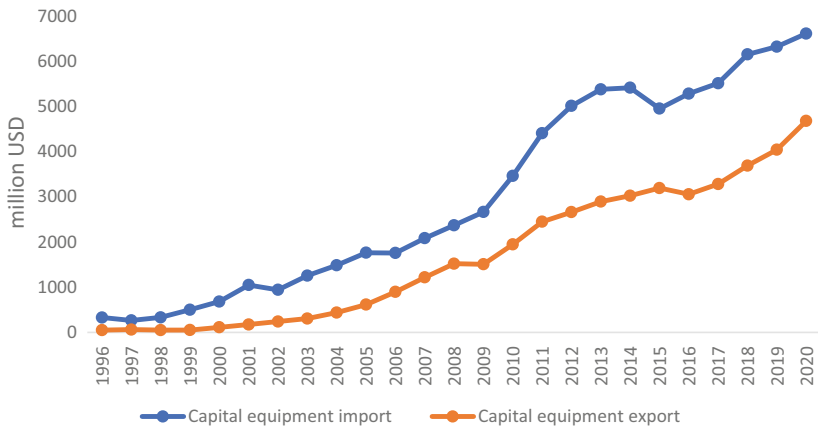


Fig. 5 China's imports and exports of high-tech medical devices with the whole world

Note The HS 6-digit codes for capital equipment is from Gereffi et al. (2019)

Source UNCOMTRADE database

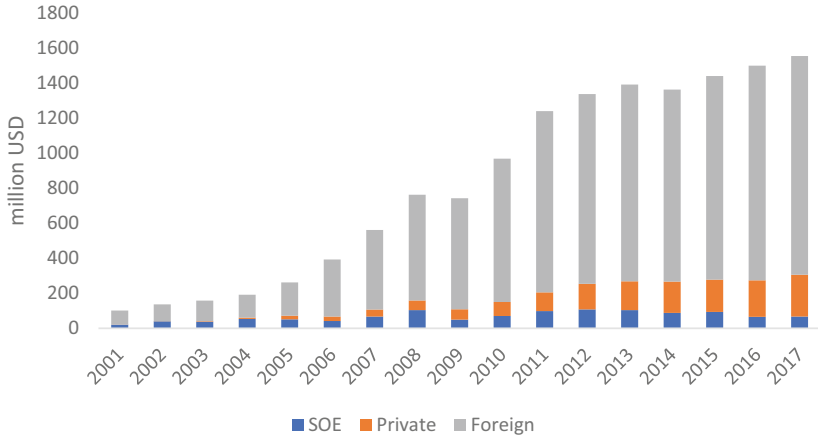


Fig. 6 China's exports of high-tech medical devices to the US and Europe by exporters' ownership
Source China's customs data

Domestic firms and foreign firms in China both contribute to the rapid export growth of high-tech medical devices. Nevertheless, foreign firms in China account for the majority of exports. Breaking down the Chinese exports of capital equipment to the advanced economies, for example, the US and Europe, 80% of exports were from foreign firms in China in 2017, 4 percentage points lower compared to 2010, while 5% and 15% were from Chinese SOEs and domestic private firms, respectively (Fig. 6).

Within the capital equipment category, if we decompose the ownership structure of Chinese exports of specific products with the highest technological complexity, such as CT and MRI, we will find that the export share of foreign firms would go up even further. For instance, in 2017, 99% of Chinese CT exports to the US and Europe were contributed by foreign firms in China, and the foreign share for Chinese MRI exports was 88%.¹ Thus, the international competitiveness of Chinese domestic firms in the global market of high-tech medical devices, particularly the most technologically sophisticated products (e.g., CT and MRI), is relatively low.

4.2.2 *Performance in the Chinese Domestic Market*

As a big economy with a rapidly aging population and increasing prevalence of chronic diseases, China has a large domestic market for high-tech

medical devices. In the past, the domestic market was occupied by international manufacturers, such as General Electric (GE, the US), Philips (Netherlands), and Siemens (Germany), which supplied Chinese hospitals and other healthcare facilities with high-end equipment, while most of the medical devices produced by Chinese domestic firms were low-cost and high-volume items. This situation is rapidly changing. Chinese domestic manufacturers are getting an increasing portion of the domestic market of high-tech medical devices.

For example, in 2019, among the top 10 firms in the Chinese domestic CT market, six of them were Chinese domestic firms (Fig. 7). In the top five firms, which accounted for 75% of the market, the market share of the international giants (GE, Philips, Siemens) was 44% combined, and the market shares of the two Chinese domestic firms, i.e., United Imaging (Shanghai City) and Neusoft Medical Systems (Shenyang City), were 17% and 14%, ranked second and fourth, respectively. By comparison, in 2017, the market shares of United Imaging and Neusoft Medical Systems in the domestic CT market were only 1% and 7%, respectively (Wei 2020). Thus, the importance of domestic brands in the domestic CT market is growing dramatically.

Another product case is MRI. Similar to the development of the CT market, Chinese domestic firms also stand out in the domestic MRI market. Specifically, in 2020, seven out of the top 10 firms in the domestic MRI market are Chinese domestic manufacturers (Fig. 7). United Imaging and Neusoft Medical Systems surged into the top five group again, accounting for 12% and 4% of the domestic MRI market, respectively. Nonetheless, the three international giants (GE, Philips, Siemens) still hold a much larger market share (72%).

4.2.3 *Upstream, Midstream, and Downstream Analyses*

The upstream of high-tech medical device GVC includes key components, which vary across final products. In general, Chinese domestic manufacturers of high-tech medical devices largely rely on imported parts and components. For example, the key components of CT manufacturing include slip rings, detectors, high-voltage generators, CT replacement tubes, and data acquisition systems. Among them, detectors, slip rings, and data acquisition systems are almost all dependent on foreign suppliers (e.g., Toshiba, Hitachi, SCHLEIFRING, Moog Inc). For high-voltage generators and CT replacement tubes, domestic producers can make low-end products, while foreign manufacturers can provide high-end items

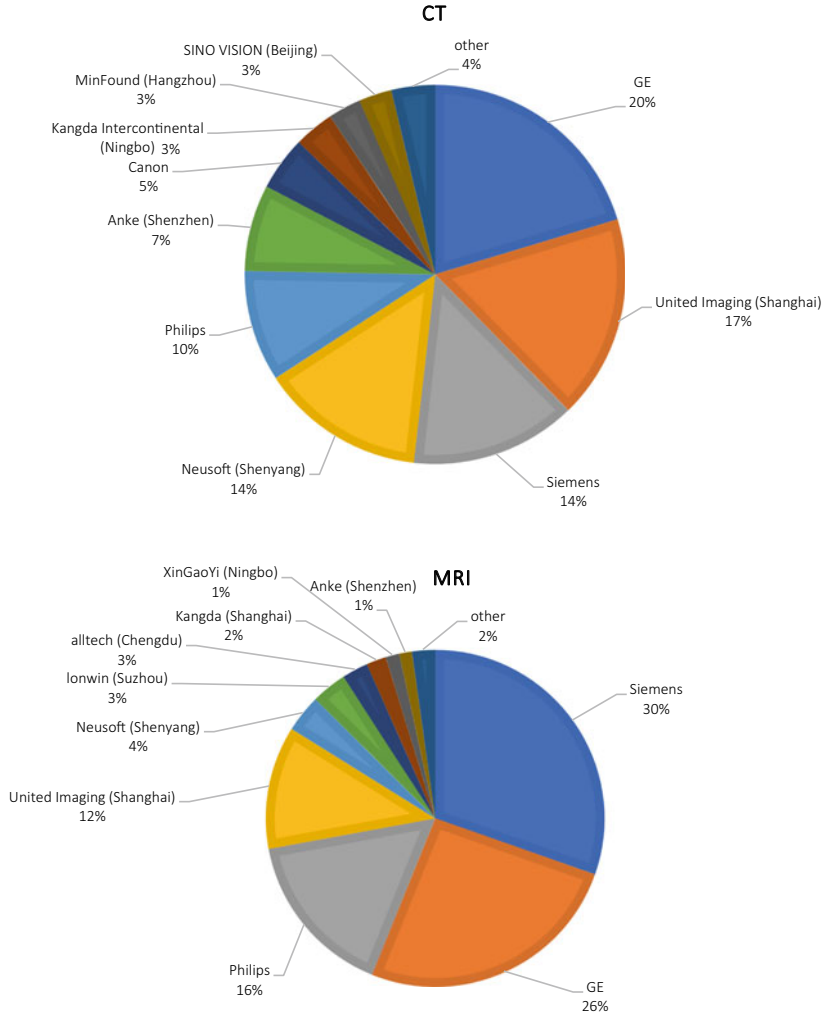


Fig. 7 Top 10 firms in the Chinese domestic CT and MRI market
Note The statistics for CT are 2019 and for MRI are 2020. For Chinese domestic firms, the headquarters are in the parentheses
Source Wei [2020], Jiankangjie Research Institute [2021]

(e.g., EMD Technologies, SEDECAL, Dunlee). The situation is similar for the upstream of the MRI GVC, which is predominantly occupied by foreign suppliers (e.g., IGC, Philips, and Mitsubishi for superconducting magnets; MR SOLUTIONS for spectrometers; Invivo, USA Instruments and Tesla for RF coils and gradient coils; and Performance Controls, Analogic and Toshiba for RF amplifiers and gradient amplifiers) (EqualOcean Intelligence 2021).

The midstream of high-tech medical device GVC is the production and assembly of final products, such as CT and MRI. Although these two devices are the most technologically sophisticated, they still have different types and varieties with varying technical complexity. Chinese domestic firms usually produce relatively medium- to low-end CT and MRI, while foreign giants produce high-end ones. For example, most of the domestic firms can only produce 1.5T MRI, and only two domestic firms (United Imaging and BASDA) register 3.0T MRI at National Medical Products Administration (NMPA), while the international manufacturers (e.g., GE, Philips, Siemens) mainly produce 3.0T MRI that generates clearer images.²

The downstream of high-tech medical device GVC are hospitals and other healthcare facilities. China has implemented a hierarchical medical system reform in recent years to improve services in small city or county hospitals, especially in less developed regions in China. The reform has promoted the development of small hospitals and increased their demand for high-tech medical devices. The domestic market share gained by local suppliers is mostly from these small city or county hospitals, rather than the large hospitals in tier-1 cities in China. Only a few domestic firms can sell to the large hospitals, which usually prefer imported and advanced devices. Furthermore, when using CT and MRI in small hospitals, they often mix the domestic and foreign devices for different medical programs. Specifically, for serious diseases which need clear images, they would use the devices supplied by foreign firms, while for simple and regular medical checks, they would use the domestic devices with lower prices (National Business Daily 2019).

4.2.4 *Firm Case Study: Neusoft Medical Systems*

As previously mentioned, most of the Chinese domestic CT and MRI manufacturers rely on imported key components. However, Neusoft Medical Systems, headquartered in Shenyang City, is an exception. It was established in 1998 and officially launched the CT-C2000 to the Chinese

domestic market in the same year, which had completely independent intellectual property rights. This is a milestone in the industrialization and commercialization of domestically developed and produced CT in China. Currently in the Chinese domestic CT and MRI markets, Neusoft Medical Systems is one of the top five CT and MRI providers. In 2020, its revenue reached 2.46 billion RMB, and it is planning to go public on the Hong Kong Stock Exchange (Beiduo Caijing 2021).

Several firm strategies helped Neusoft Medical Systems grow and compete with the international giants in the Chinese domestic market. First, it made technological breakthroughs on key components of CT, and built the whole value chain within the firm. In other words, it can produce CT on its own, without inputs from other domestic or foreign firms. Therefore, during the pandemic its production was not disrupted and its performance was record-breaking. Specifically, it developed and provided NeuThor mobile CT containers to Wuhan and other affected cities in China within 15 days of the outbreak as well as other countries such as Chile (Block Imaging 2020; Wu and Zhou 2020).

Second, Neusoft Medical Systems focuses on innovation, not only for key components but also innovative products. The firm's goal is to be an excellent value innovator of global healthcare services. In 2020, its R&D spending was 0.22 billion RMB, which increased by 22.6% compared to 2019, and its R&D intensity (R&D spending relative to revenue) reached 9% (Beiduo Caijing 2021). On the one hand, innovation in the key components allows the firm to reduce its reliance on others, particularly foreign suppliers, which was extremely critical during the pandemic. On the other hand, innovation on the final products helps the firm to build brand reputation and increase sales.

For example, before 2017, most of the domestically produced CT machines were 16-slice and 64-slice CT, and the relatively high-end domestic products were 128-slice CT. However, in recent years, Neusoft Medical Systems innovated and developed the 256-slice CT (NeuViz Glory), which helped the firm break into the high-end CT market that was dominated by foreign manufacturers (Wei 2020). At the same time, Neusoft Medical Systems is also developing MDaaS (Medical Devices & Data as a Service), a strategic product line built by combining digital technologies (e.g., big data and artificial intelligence) and other technologies, to improve medical institutions' ability to diagnose and treat patients. Innovation has been the driving force of the firm's growth. It has built R&D centers in Houston, Seoul, Beijing, Shanghai, Shenyang,

Guangzhou, and Nanjing, partnering with the medical, academic, and research communities (Neusoft Medical Systems 2022a).

Finally, product diversification is an important strategy. Initially, the firm only had one CT product line. But now it has eight kinds of products, including CT, MRI, DSA (digital subtraction angiography), XR (extended reality), PET/CT (positron emission tomography), RT (radiotherapy), US (ultrasound diagnostics), and IVD (in vitro diagnostic products), covering almost all aspects of radiography, routine examination, radiotherapy and nuclear medicine, and clinical applications (Neusoft Medical Systems 2022b). Because of this diversification strategy, Neusoft Medical Systems became one of the few firms with complete product lines in the field of medical imaging in China. Other non-firm-specific factors, which also contribute to the upgrading of Neusoft Medical Systems, will be discussed in Sect. 5.

5 DISCUSSION

5.1 *Driving Forces Behind the Upgrading of Chinese Domestic Firms in the Past*

5.1.1 *Large Domestic Market*

China is the largest and fastest growing market in the world for industrial robots, and the second largest market for high-tech medical devices. The large domestic market has provided growth and upgrading opportunities for both Chinese and foreign manufacturers. Although Chinese domestic firms have relatively lower production and innovation capabilities compared to their foreign counterparts, they have comparative advantages in terms of lower prices, better fit of local consumer preferences, and stronger connections with downstream local firms. In the past decades, China's large domestic demand has allowed the domestic producers to grow and accumulate capital, technologies and experiences, and then gradually upgrade and provide innovative products with higher qualities. This upgrading trajectory of industrial robots and high-tech medical devices is similar to the development of the mobile phone sector in China (Gereffi et al. 2021): at first, the domestic firms provided slightly lower quality but much cheaper alternatives to foreign produced high-end phones; and later on, when the domestic firms accumulated enough resources, they could make significant technological breakthroughs and become internationally competitive.

5.1.2 *National Priority*

The development of industrial robots as well as high-tech medical devices has become one of the top national priorities in China since 2015. In a bid to move manufacturing up the value chain, the State Council issued the “Made in China 2025” program in 2015, which intended to boost technological innovation, create and shape home-grown brands, and promote breakthroughs in 10 key sectors, including “numerical control tools and robotics” and “biological medicine and high-tech medical devices”. Later on, the central government launched various national plans that include multiple measures such as industrial cluster establishment, fiscal subsidies, tax refund, ease of financing, human capital development, government procurement, business environment reforms, and international cooperation, which greatly contributed to the upgrading of domestic firms in the industrial robots and high-tech medical devices GVCs in recent years. Additionally, these plans usually set explicit national targets. For example, “Robot Industry Development Plan (2016–2020)” set national goals of producing 100,000 units of industrial robots per year by domestic producers and having 150 robots in operation for every 10,000 employees (i.e., robot density) by 2020. Detailed policies by the central government are listed in the Appendix (Tables 1, 2).

5.1.3 *Local Policy Support*

Following national strategies by the central government, local governments implemented a variety of policies on industrial robots and high-tech medical devices. The local policies on robots are usually comprehensive, covering different segments of the whole value chain (i.e., upstream, midstream and downstream), while those for high-tech medical devices are mostly focused on downstream application of domestically produced devices. For example, Foshan municipal government set up special support funds for industrial robots, with an annual contribution of 130 million RMB during 2018–2020. And the funds were allocated to manufacturers of key components, robot-body producers, robot system integrators, and robot adopters, with maximums of 8 million RMB, 5 million RMB, 5 million RMB, and 3 million RMB per firm, respectively. Meanwhile, the Foshan government regulated imports of medical devices by government procurement, which applied to government departments, public hospitals, public universities, and research institutions, in order to promote the purchase and usage of domestically produced devices. After certain evaluation procedures, medical devices are only allowed to be

imported when similar domestic products are not available. For instance, only 72 types of medical devices can be imported in Foshan in 2016. Detailed policies by the local governments are listed in the Appendix (Tables 3, 4).

5.1.4 *Innovation*

Successful firm cases (e.g., Estun and Neusoft Medical Systems) suggest that innovation has been a driving force behind the upgrading of Chinese domestic firms in the industrial robots and high-tech medical devices GVCs. The technological breakthroughs on key components and innovative final products helped domestic firms break into the high-end market. In the two sectors, China's patents grew dramatically in the 2010s. Specifically, the medical devices patents granted by the Chinese IP office increased from 4263 in 2010 to 36,926 in 2019 (Joinchain 2020). During this period, China also became one of the top five economies patenting in robotics, along with the US, Japan, South Korea, and Germany (Abdulla 2021).

5.1.5 *External Factors*

In addition to the internal factors, there are several external factors that have pushed the upgrading of Chinese domestic firms in the two sectors. First, in the last decade, the industrial robots and high-tech medical devices GVCs expanded rapidly worldwide. Other major manufacturing economies also implemented national plans to promote the development of these two sectors, for example, the Industry 4.0 plan and High-Tech Strategy 2025 in Germany and the New Robot Strategy in Japan (Ballinger 2021). The growth of the global markets created growth and upgrading space for Chinese domestic firms.

Second, FDI facilitated the upgrading of Chinese domestic firms through intense competition and technological spillovers. For example, major international robot producers have invested in China. FANUC (Japan) has established a subsidiary in Shanghai (Shanghai-FANUC Robotics Co., Ltd.) and Yaskawa Electric Corporation (Japan) has built three manufacturing factories in China that can produce 18,000 units of robots every year (Gongkong 2018).

Third, the pandemic boosted the growth of the two sectors in China. Specifically, the pandemic spurred the demand for high-tech medical devices globally, and at the same time, it disrupted the global supply chain of high-tech medical devices, but China has managed to recover rapidly

from the supply interruptions and scale up the production to meet the surging demand (Gereffi et al. 2022). The situation of industrial robots is similar.

Finally, the recent trade tensions between the US and China affected Chinese firms, as industrial robots and some high-tech medical devices were included in Section 301 tariff lists. Almost half of the US diagnostic equipment imports (US\$ 457 million annually) from China were subject to Section 301 tariffs (US Chamber of Commerce China Center 2021). Among other effects, the trade frictions eroded the export competitiveness of Chinese producers and may shift their development focus to the domestic market. Nonetheless, during the pandemic, import tariffs on a large number of medical devices were temporarily suspended, including CTs and MRIs.

5.2 *Driving Forces that Will Continue Pushing Upgrading in the Future*

5.2.1 *Large Domestic Market*

The large domestic market will remain a key driving force of upgrading in the future because the domestic demand for industrial robots as well as high-tech medical devices will continue to grow in China. First, a rapidly aging population will keep increasing the demand for both sectors in China.

Second, China's intensity of demand for industrial robots and high-tech medical devices is still relatively lower than those in the advanced economies. For example, in 2020, China's robot density in the manufacturing sector ranked ninth globally (246 units per 10,000 manufacturing workers), while South Korea had the highest robot density (932 units per 10,000 manufacturing workers) (Xinhua 2021). Also, the CT intensity (the number of devices per million population) in China is 18.6, one half of that in the US and one-fifth of that in Japan (Wei 2020). Thus, China still has much space to catch up.

Finally, the current development of downstream clients in China will generate great growth potential for domestic producers of industrial robots and high-tech medical devices. Specifically, the construction of digital infrastructure and growth in electric vehicles will bring opportunities to the electronics and automotive sectors in China, which are the top two robot-adopting industries. Meanwhile, continuing reform of the

hierarchical medical system in China will largely promote the development of small-city and county hospitals, and thus increase their demand for affordable high-tech medical devices.

5.2.2 *National Priority*

The industrial robots and high-tech medical devices will still be national priorities in the coming years. In 2021, China released the 14th Five-Year Plan (2021–2025), which included the robotics industry as well as the high-end medical devices industry. Later the central government issued the specific plans for the two industries, i.e., “14th Five-Year Robot Industry Development Plan” and “14th Five-Year Medical Equipment Industry Development Plan”, aiming at promoting innovation, high-end production, and applications. Policy tools, such as fiscal and financing support, intellectual property protection, human capital development, and international cooperation, will continue to play a role in upgrading. Additionally, in 2021 the central government announced the “Guidelines for the Review of Government Procurement of Imported Products”, which included domestic purchase requirements on different types of medical devices.

5.2.3 *Local Policy Support*

Following the national guidelines by the central government, local governments will also roll out policies to support the development of industrial robots as well as high-tech medical devices. For example, in the “14th Five-Year Plan for the High-Quality Development of Manufacturing in Guangdong Province”, the Guangdong provincial government listed the two sectors as strategic industries and will foster two industrial clusters that both center on Guangzhou, Shenzhen, Zhuhai, and Foshan. At the same time, the Guangdong government also reduced the number of imported medical devices on the government procurement list from 132 to 46 in 2021.

5.2.4 *Innovation*

The role of innovation in upgrading will be strengthened in the future. China is transforming from “investment-driven” to “innovation-driven” growth and public–private partnerships on innovation of robots and high-tech medical devices are evolving. For example, a national robot innovation center has been built, consisting of both public research institutions (e.g., Harbin Institute of Technology, Shenyang Institute of

Automation) and Chinese domestic firms (e.g., SIASUN, BOSHIAC, EFORT). This public–private cooperation is extremely important, as most of the robotics patents are filed by universities and public research institutes in China, while firms are top patent-filing entities in the advanced economies (Abdulla 2021). The translation from patents to production will become faster in the public–private cooperation framework. Similarly, China has also established a national high-end medical device innovation center in Shenzhen, including both public research institutes (e.g., Chinese Academy of Sciences, Shenzhen Institute of Advanced Technology, and Harbin Institute of Technology) and Chinese local firms (e.g., Mindray and United Imaging).

5.2.5 *External Factors*

Looking forward, external factors, such as FDI, trade frictions, and the pandemic, will continue affecting the upgrading of Chinese domestic firms in the two sectors. Specifically, the ongoing pandemic will further escalate the global demand for industrial robots due to lockdowns and social distancing rules, as well as the global demand for high-tech medical devices for medical treatment purposes. Additionally, the Regional Comprehensive Economic Partnership (RCEP) that came into effect on January 1, 2022 will impact multiple manufacturing GVCs, including the industrial robots and high-tech medical devices GVCs. China's domestic producers face both opportunities (e.g., more varieties of intermediates with higher qualities and lower costs) and challenges (e.g., more intense competition). The overall effects remain to be seen.

5.3 *Comparison of GVC Upgrading in the Two Sectors*

The upgrading patterns of Chinese domestic firms in the two sectors, i.e., industrial robots and high-tech medical devices, have some commonalities. Specifically, local Chinese firms are relatively weak in terms of international competitiveness, i.e., foreign MNEs in these two sectors dominate China's exports. Nonetheless, Chinese firms have built competitiveness in the domestic market. They exploited China's large domestic market, gradually added significant production and innovation capabilities in both sectors, and thus gained an increasing share in the domestic market. Of critical importance, in both sectors successful local firms are those that made technological breakthroughs and became self-sufficient in key components production.

Similar factors have driven the upgrading of domestic firms in the two sectors in the past as well. These include China's large domestic market, national guidance by the central government, policy support by local governments, innovation, and external factors (e.g., growth of the global markets, FDI, the pandemic, and the global policy environment). These factors will continue to shape upgrading in both sectors in years to come.

Nevertheless, there are also key differences between the two sectors in terms of upgrading paths and strategies. One major difference, for example, is that the downstream users of industrial robots are mostly firms, while buyers of high-tech medical devices are hospitals, the majority of which are state-owned. Based on the above policy analyses, we find that policies on industrial robots are usually comprehensive, i.e., each policy document covers upstream, midstream, and downstream segments of the industrial robot GVCs. However, for the high-tech medical device GVCs, although some policies aim at innovation and production, most policies focus on the downstream adoption of domestic medical devices, especially in small hospitals and in lower-tier cities. Thus, government procurement is used as a tool to achieve localization in the high-tech medical device sector, while it is very rarely utilized in the industrial robot sector.

6 CONCLUSION AND POLICY IMPLICATIONS

Currently China's local firms are relatively weak in the global markets of industrial robots and high-tech medical devices, while they are rapidly increasing their participation in the large and growing domestic market. Thus, China's burgeoning domestic market greatly facilitates the upgrading of domestic firms in both sectors, which has implications for other developing economies with large domestic markets.

Innovation is a key driver for the upgrading of Chinese domestic firms. Various strategies have been used to promote innovation, particularly the technological breakthroughs on production of key components, which are dominated by foreign MNEs in the two sectors. Public-private partnerships on innovation emerge in both sectors, which is extremely important for domestic industrial robot producers, as most of the robot patents are owned by the public research institutions in China. This suggests that the Chinese government should take more measures to incentivize the private sector (i.e., domestic firms) to innovate. It should also incentivize the collaboration between research institutions and local firms to

leverage the thousands of patents already developed for commercialization. In addition, FDI inflows and domestic firms' M&A activities generate technological spillover effects and thus assist the upgrading of domestic manufacturers.

Policy support by the central and local governments pushes domestic firms to move up the value chains of both sectors. Various policies focus on local firms, domestic technologies and Chinese brands. While policy support for the industrial robot sector covers all segments of the GVC, that for high-tech medical devices emphasizes product localization in the downstream hospitals. The latter may benefit domestic medical device suppliers but to the detriment of participation by foreign MNEs, which may adversely affect the size of the domestic market and the potential of technology spillovers that could promote upgrading of domestic firms in the longer term. Therefore, policymakers should reevaluate the intended as well as unintended consequences of these policies.

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NOTES

1. The HS 6-digit code for CT is 902212, and that for MRI is 901813.
2. T stands for tesla, a unit of measurement to define the magnetic flux density. As MRI scanners are created with varying magnetic field strength, they are measured in tesla (T).

APPENDIX

See Tables 1, 2, 3, 4.

Table 1 China's central government's policies on robots (non-exhaustive list)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2015	State Council	Made in China 2025	Robot is one of 10 key sectors. The main tasks are: <ol style="list-style-type: none"> 1. Develop new products and promote robot standardization and modules 2. Develop and expand market applications 3. Break through the technical bottlenecks of key components, such as robot body, reducer, servo motor, controller, sensor, driver, and system integration design and manufacturing
2016	State Council	13th Five-Year Plan	Promote the innovation and industrialization of emerging frontier fields, such as robotics
2016	Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Finance	Robot Industry Development Plan (2016–2020)	The main targets are: <ol style="list-style-type: none"> 1. The scale of the robot industry should continue to grow. The annual output of domestically produced industrial robots should reach 100,000 units per year by 2020. The annual sales revenue of service robots should exceed 30 billion RMB. By 2020, China should cultivate more than 3 leading domestic firms with international competitiveness and create more than 5 robot supporting industrial clusters 2. The level of robot technology should be significantly improved by 2020 3. China should make major breakthroughs in key components of robots, with a market share of more than 50% 4. China should achieve large-scale applications of robots in key industries. The robot density should be higher than 150 units per 10,000 employees

(continued)

Table 1 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2016	Ministry of Industry and Information Technology, National Development and Reform Commission, National Certification and Accreditation Administration	Notice on Promoting the Healthy Development of the Robot Industry	The main tasks are: 1. Promote the rational development of the robot industry 2. Strengthen technological innovation capabilities 3. Accelerate the transformation of innovative scientific and technological achievements 4. Strengthen key breakthroughs such as parts and components 5. Develop industrial robot application market 6. Promote pilot demonstrations of service robots 7. Establish a certification system 8. Implement “Industrial Robot Specification Conditions” 9. Improve the fair competition in the robot industry 10. Encourage robot enterprises to participate in talent training
2021	State Council	14th Five-Year Plan	Promote innovation development of robots, along with other advanced manufacturing industries
2021	15 Ministries ¹	14th Five-Year Robot Industry Development Plan	The main tasks are: 1. Improve industrial innovation capabilities 2. Consolidate the foundation of industrial development 3. Increase the supply of high-end products 4. Expand application depth and breadth 5. Optimize the industry’s organizational structure

Source Authors’ compilation

¹Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Science and Technology, Ministry of Public Security, Ministry of Civil Affairs, Housing and Urban–Rural Development, Ministry of Agriculture and Rural Affairs, National Health Commission, Emergency Management Department, People’s Bank of China, State Administration for Market Regulation, China Banking and Insurance Regulatory Commission, China Securities Regulatory Commission, State Administration of Science, Technology and Industry for National Defense, State Mine Safety Supervision Bureau.

Table 2 China's central government's policies on high-tech medical devices (non-exhaustive list)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2015	State Council	Made in China 2025	Improve the innovation capability and industrialization level of medical devices Focus on the development of high-tech diagnosis and treatment equipment such as imaging equipment and medical robots, high-value medical consumables such as fully degradable vascular stents, and mobile medical products such as wearables and remote diagnosis and treatment
2015	State Council	Outline of the National Medical and Health Service System Plan (2015–2020)	Gradually improve the allocation level of domestic medical equipment
2015	State Council	Guiding Opinions on the Pilot Program of Comprehensive Reform of Urban Public Hospitals	Public hospitals give priority to domestic medical equipment
2016	State Council	Guiding Opinions on Promoting the Healthy Development of the Pharmaceutical Industry	In principle, government procurement projects must purchase domestic products, and gradually improve the level of domestic equipment allocation in public medical institutions
2016	State Council	Outline of the Healthy China 2030 Plan	By 2030, the international market share of new drugs and diagnosis and treatment equipment with independent intellectual property rights will be greatly increased, and the localization rate of the high-end equipment market will be greatly increased

(continued)

Table 2 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2017	State Council	Opinions on Deepening the Reform of the Review and Approval System and Encouraging the Innovation of Drugs and Medical Devices	Promote the localization of medical devices and promote the application and promotion of innovative products
2021	State Council	14th Five-Year Plan	Develop high-end imaging, radiotherapy, and other large medical equipment and key components
2021	10 Ministries ¹	14th Five-Year Medical Equipment Industry Development Plan	<ol style="list-style-type: none"> 1. Identify 7 key medical equipment, including diagnostic equipment 2. Improve innovation capacity 3. Strengthen medical-industrial collaboration 4. Strengthen domestic brands building and improve international competitiveness 5. Cultivate new business models, such as 5G+ medical service 6. Optimize the industry's ecology, such as improvements of standards
2021	Ministry of Finance, Ministry of Industry and Information Technology	Guidelines for the Review of Government Procurement of Imported Products	137 kinds of medical devices all require 100% domestic procurement; 12 kinds of medical devices require 75% of domestic purchases; 24 kinds of medical devices require 50% of domestic purchases; 5 kinds of medical devices require 25% of domestic purchases

(continued)

Table 2 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2021	State Administration of Taxation	Measures for the Administration of VAT Refunds for the Purchase of Domestic Equipment by R&D Institutions	R&D institutions which purchase domestic equipment will get the full VAT refund

Source Authors' compilation

¹Ministry of Industry and Information Technology, National Health Commission, National Development and Reform Commission, Ministry of Science and Technology, Ministry of Finance, State-owned Assets Supervision and Administration Commission of the State Council, State Administration for Market Regulation, National Medical Insurance Administration, State Administration of Traditional Chinese Medicine, State Drug Administration.

Table 3 China's local governments' recent policies on robots (non-exhaustive list)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2019	Beijing	Robot Industry Innovation and Development Action Plan (2019–2022)	The main targets are: 1. Cultivate and form more than 3 national influential collaborative innovation platforms 2. The city's robot industry revenue exceeds 12 billion RMB

(continued)

Table 3 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2018	Jiangsu Province	Three-Year Action Plan for the Development of Robotics Industry (2018–2020)	<p>The main targets by 2020 are:</p> <ol style="list-style-type: none"> 1. The output of the province's robot industry will reach 100 billion RMB, with an average annual growth rate of more than 35%. The annual output of domestically produced industrial robots will reach 10,000 units, forming a group of leading domestic robot enterprises, well-known brands, and industrial bases 2. The province should establish a batch of national and provincial robot innovation platforms and public service platforms 3. The province should set up a group of robot promotion and application centers
2017	Zhejiang Province	“Robot plus” Action Plan	<p>The main targets by 2020 are:</p> <ol style="list-style-type: none"> 1. The province should build 30 innovation carriers above the municipal level and organize more than 50 key technology research projects and more than 50 industrialization projects 2. The number of operational industrial robots should reach 100,000 units, and the robot density should reach more than 120 units per 10,000 manufacturing workers 3. The sales revenue of the robot industry should exceed 150 billion RMB, and a number of robot industrial parks or towns with an output of more than 5 billion RMB should be built 4. The province should encourage the development of new business models of “Robot plus”

(continued)

Table 3 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2014	Shenzhen	Robot, Wearable Device and Intelligent Equipment Industry Development Plan (2014–2020)	<p>The city has an “Industrial Robots Leapfrogging Project”. The main tasks are:</p> <ol style="list-style-type: none"> 1. Implement differentiated development strategies around key components, robot bodies, system integration, and terminal applications 2. Organize major technical research projects, make breakthroughs in a number of core technologies, and enhance independent innovation capabilities 3. Strengthen the integration and innovation of information network technology and robot technology and realize the intelligentization and multi-functionalization of industrial robots 4. Organize and implement a number of industrial robot research and development and industrialization projects and accelerate the cultivation of independent brands and innovative enterprises 5. Plan to build a robot industrial park, cultivate and introduce a group of industrial robot R&D, manufacturing and system integration enterprises and key basic components supporting enterprises to form an industrial robot industrial cluster with strong competitiveness and distinctive characteristics 6. Focus on promoting the application of industrial robots in the 3C industry and promote the rapid development of the industrial robot industry and application

(continued)

Table 3 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2018	Foshan	Promoting Robot Application and Industrial Development Program (2018–2020)	The main targets by 2020 are: 1. The city will promote additional 600 medium- to large-size industrial enterprises to apply robots 2. The city will build 10–15 intelligent manufacturing demonstration enterprises with robot application as the core 3. The city will support more than 50 robot R&D, manufacturing, and system integration pillar enterprises 4. The city will build more than 5 high-level public service platforms for robots and intelligent manufacturing 5. The output of the robot and intelligent equipment industry will exceed 120 billion RMB, with an average annual growth rate of more than 15% 6. From 2018 to 2020, the municipal finance will set up special support funds for robots, with an annual fund of 130 million RMB
2016	Dongguan	Opinions on Vigorously Developing the Robot Intelligent Equipment Industry and Building an Advanced Manufacturing Base with Global Influence	The targets by 2020 are: 1. The output of the robot and intelligent equipment industry will reach 100 billion RMB, with an average annual growth rate of 30% 2. Industrial robots should be widely used in electronics, machinery, food, textile, furniture, and other industries, and service robots are used in household services, education and entertainment 3. The number of robots used by every 10,000 employees should increase to more than 120 4. 2 to 3 industrial robot industrial parks and 10 intelligent equipment industrial bases should be built to form a relatively complete robot industrial system

(continued)

Table 3 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2021	Chongqing	Work Plan for Promoting High-Quality Development of the Robotics Industry (2021–2025)	By 2023, the sales revenue of Chongqing’s robot industry will exceed 50 billion RMB, and breakthroughs in core technologies such as drive and control will be achieved, and a good industrial ecology with demand matching, business linkage, and operation coordination will be initially built. By 2025, the sales revenue will exceed 80 billion RMB, and the application of robots in various fields of industrial production will make great progress. A batch of new robot business models will be formed, and a domestic first-class robot application demonstration base, as well as an industrial innovation and development demonstration area will be built.

Source Authors’ compilation

Table 4 China’s local governments’ recent policies on high-tech medical devices (non-exhaustive list)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2017	Sichuan Province	Announcement of the 2017 Provincial Government Procurement List of Imported Products	Hospitals (or units) below Grade AA should use domestic products, and only hospitals above Grade AA (large hospitals) are allowed to purchase imported products.
2021	Sichuan Province	2021–2022 Provincial Government Procurement List of Imported Products Demonstration Announcement (Medical and Healthcare Equipment)	Only 59 types of medical devices can be imported, and the rest of medical devices should be domestic.

(continued)

Table 4 (continued)

<i>Time</i>	<i>Authorities</i>	<i>Policy name</i>	<i>Policy content</i>
2021	Zhejiang Province	2021–2022 Provincial Government Procurement Unified Demonstration List of Imported Products (Medical Equipment)	The number of imported medical devices on the government procurement list is reduced from 215 to 195 in 2021
2021	Guangdong Province	Announcement of the 2021 Provincial Health Organization List of Imported Products	The number of imported medical devices on the list is reduced from 132 to 46 in 2021
2021	Shaanxi Province	Administrative Measures for Government Procurement of Imported Products by Budget Units	The regulation procedures for importing medical devices become much stricter
2021	Kunming	Notice on Matters Related to Regulating the Approval of Government Procurement of Imported Products	Firms can only import medical devices if domestic products with the same quality are not available, and firms need to submit the comparison report on the imported product and three similar domestic products

Source Authors' compilation

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