Why is Siemens establishing its robotics R&D centers in China? A case study on the Siemens industrial robot project

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***Abstract*—China has been transforming its development strategy from an investment-driven to an innovation-led one. Recent government policies (e.g., "Made in China 2025") have shown the country's ambition to upgrade its manufacturing industry. Meanwhile, the technological environments and market conditions in China have also been changing rapidly. All these changes in terms of government policies, technological environments, and market conditions bring both opportunities and challenges for multinational enterprises (MNEs) in China. How should MNEs react to such new realities? As one leading MNE with a long history in the Chinese market, Siemens has been adapting its global R&D strategies, establishing its R&D centers of industrial robots in China. This represents an interesting case to academic researchers, industry practitioners, as well as policy makers. To better understand the co-evolution of MNEs and China's innovation systems, we conducted this case study project on the Siemens innovation about industrial robots. The research shows that, on the one hand, Siemens' decision of conducting R&D on industrial robots in China is driven by China's evolving host-country environments. On the other hand, the changing R&D strategies of Siemens in China also have impacts on China's innovation system, helping domestic manufacturers to make more advanced robots.**

***Index Terms*—co-evolution, MNE, innovation system, China, industrial robot**

I. Introduction

After 40 years of development since China re-opened its door in 1978, China has made impressive progress in terms of industrial development. The country has gradually transformed itself from an "imitator" to an "innovator". The evolution of China's innovation system means that the host-country environments facing foreign MNEs in China have also been changing. This leads to two important questions: First, how should MNEs adapt their R&D strategies during China's transformation into an innovation-led economy? Second, what impacts will the changing R&D strategies of MNEs bring to China's innovation system?

Prior literature on MNEs has explained well the evolution of MNEs' R&D strategies, from "home-country-based" R&D [1] to "host-country-based" R&D [2], and then to globalized R&D. Meanwhile, prior studies on innovation systems have expanded the notion of innovation systems from "national innovation system" [3] [4] to "global innovation system" [5]. However, limited attention has been paid to the interactions between MNEs and their host-country environments. This research aims to fill in this gap by examining the co-evolution of MNEs and host-country environments in the context of China's transition into an "innovation-led" economy.

II. Literature review

Early research on MNEs (e.g., [6]) suggests that the R&D activities of MNEs tend to be concentrated within their home country, because the competitive advantages of MNEs often come from knowledge that is "sticky" to their home country. Even if some MNEs conduct R&D activities overseas, these R&D activities are mainly focused on adapting existing technologies for the local market [7] [8]. These arguments are consistent with the main stream international business (IB) literature at that time (e.g., Dunning's eclectic theory of internationalization), which suggests that MNEs can exploit their ownership advantages (e.g., superior technologies/brands) overseas. And, such ownership advantages would compensate for MNEs' liability of foreignness in foreign markets [9]. One key assumption underlying this stream of arguments is that MNEs originated in advanced economies, which had sufficient supply of knowledge to support the R&D activities of MNEs.

However, the world has witnessed increasing amount of R&D-based FDI since 1980s. This trend was first observed within developed economies, and later expanded into other emerging economies. Based on such observations, Kuemmerle proposed two different types of home-country-based overseas R&D, called "home-base-exploiting, HBE" and "home-base-augmenting, HBA" [1]. The former mainly focuses on exploiting the existing knowledge from the home country, whereas the latter mainly focuses on enhancing the capabilities of MNEs' home-base by sourcing knowledge from the host-country. Wang, Xue and Liang proposed another perspective for understanding MNEs R&D activities, according to which MNEs can implement a "host-country-based" approach for conducting R&D [2]. Wang, Liang and Xue further investigated 31 overseas R&D units of 24 MNEs in China [10]. They identified four different types of multinational R&D units in China, including Technology Competence Unit (TCU), System Competence Unit (SCU), Support Unit (SU), and Assignment Unit (AU). The driving resources and governance mechanisms differ among these four types of R&D units.

In their seminal Harvard Business Review article, *How GE is disrupting itself*, Immelt, Govindarajan, and Trimble [11] explained how GE leveraged on its "local growth teams" in emerging markets to develop innovative products (e.g., portable ultrasound machines). Such products were initially developed to solve problems in emerging markets. But later, they had shown their significant impacts on the advanced markets as well. The notion of "reverse innovation" is further coined by Govindarajan & Ramamurti [12] and Govindarajan & Trimble [13], who suggest that innovative ideas can also flow from subsidiaries in emerging economies back to headquarters in advanced economies. Whether a subsidiary will be "competence-exploiting" or "competence-creating" depends on location-specific, subsidiary-specific, and group-specific factors [14]. These developments in theories of MNE R&D strategies are echoed by the "springboard perspective" in the IB literature, which argues that MNEs (especially emerging-market MNEs) can consider internationalization as a way to overcome their competitive disadvantages [15].

As China is becoming a more and more important destination for overseas R&D activities, scholars have paid increasing attentions to MNEs' R&D activities in China. For example, Gassmann & Han [16] examined the motivations behind foreign R&D activities in China, and they found different motivations, such as exploiting qualified human capital, local adaptation, government policies and so on. The authors also found that foreign MNEs faced different challenges for conducting R&D in China. These challenges include (but not limited to) the lack of loyalty from their local employees, bureaucracy, uncertain policy changes, and weak IPR protection.

However, China's innovation system has been evolving rapidly. First, the country's innovation capacity has been enhanced over the past decade. For example, the number of PCT patents from China has increased from approximately 781 in 2000 to approximately 43128 in 2016. According to the Innovation Index published by Bloomberg [17], China has been ranked 21st among 50 most innovative economies in the world. Second, China has transformed itself from a low-income country into an upper-middle-income country. The average annual salary of an urban worker in China has increased from approximately 18,200 RMB to 62,029 RMB. This changing trend has two implications. On the one hand, this means that China is losing its competitive advantages in terms of cheap labor. On the other hand, this means that there are more Chinese consumers who can afford more expensive and better-quality products. Third, the government has shown increasing commitment to transforming the country into an innovation-led economy. This leads to the implementation of a series of new policies/plans (e.g., Made in China 2025). Finally, the technological regimes *per se* have also been changing rapidly. The advent of emerging technologies (e.g., AI and "intelligent manufacturing") is re-drawing the boundaries of sectors.

All these changes require foreign MNEs in China to have sufficient dynamic capabilities [18] to adapt their strategies according to the changing environments. What remain less clear are the following questions: How should MNEs adapt their R&D strategies during China's transition into an "innovation-driven" economy? And, what impacts will the changing R&D strategies of MNEs have on China's innovation system?

III. Theory

This study adopts a co-evolutionary perspective to examine the above questions. The co-evolutionary perspective has been used in prior studies (e.g., [19]) to explore how certain actors co-evolve with their surrounding environments. In recent years, China's innovation system has been changing rapidly. And, we argue that foreign subsidiaries of MNEs in China are important components of China's innovation system, since access to foreign knowledge is critical for domestic firms' catching-up [20]. Thus, the R&D strategies of MNEs in China will be influenced by the evolution of China's innovation systems, and their activities will also influence the evolution of China's innovation system. For example, Siemens decided to establish its global R&D center of industrial robots in China, around more or less the same time that the country announced its "Made in China 2025" plan. This is probably not a coincident. A co-evolutionary perspective allows us to better understand why (and how) Siemens established its R&D centers of industrial robots in China.

The notion of "innovation system" has a long history in innovation studies, which refers to a system that consists of different actors (e.g., firms, governments, universities, public research institutions) and "the rules of the game" that determine how these actors play within the system [21]. Depending on the level of analysis, different scholars developed concepts such as "national innovation system" [3] [4], "sectoral system of innovation" [22], and "open national innovation system" [30]. A common theme in this "innovation system" approach is how an innovation system can promote "learning and capability building" within the system.

Foreign subsidiaries of MNEs in China are recognized legal entities in China. And, they can provide China's innovation system with an important "access to foreign knowledge" through their (1) interactions with domestic firms (e.g., competitors, customers, and suppliers); (2) interactions with universities and public research institutions; (3) interactions with governments. Therefore, foreign subsidiaries of MNEs in China should be considered as part of China's innovation system. We argue that MNEs are co-evolving with China's innovation system. On the one hand, the evolution of China's innovation system will have impacts on the R&D strategies of MNEs; while on the other hand, the evolution of the R&D strategies of MNEs will also have impacts on China's innovation system.

When the innovation capacity of the host-country is very low, MNEs will not deploy sophisticated R&D activities to this country, because conducting such R&D activities would require qualified human capital, innovative collaborators, and supporting institutions. As the innovation capacity of the host-country increases, the R&D activities of foreign MNEs in this country will also increase.

For example, over the past decades, China's innovation capacity has been increased significantly. This means that China can provide MNEs with more qualified personnel for sophisticated R&D activities. At the same time, the labor cost in China has also been rising rapidly. This means that China is becoming a less attractive place for conducting low-value-added R&D activities (e.g., simple modification of existing technologies). According to the director of an MNE's research laboratory in China, the salary of an Artificial Intelligence (AI) researcher is not lower than the salary of an AI researcher in his home country. The reason why they still conduct R&D in China is because of the "talent" and "excellence" of Chinese researchers. The evolution of China's innovation system (e.g., increasing innovation capacity as well as increasing labor costs) will have impacts on the R&D strategies of MNEs. MNEs may need to either shift more high-value-added R&D activities to China, or they may divest from China as the country is becoming less attractive for low-value-added R&D activities.

Proposition 1: The R&D strategies of MNEs (e.g., Siemens) are shaped by the evolution of China's innovation system;

At the same time, the changing R&D strategies of MNEs also have impacts on the host-country's innovation system. As MNEs increase their R&D activities in China, they will bring "knowledge spillover" effect [23] to the host-country's innovation system through their interactions with different players within the host-country's innovation system.

For example, in the early days, the R&D activities of MNEs in China were mainly focused on customizing existing technologies to serve the local needs. Overtime, more and more MNEs upgraded their R&D activities in China either by conducting R&D internally or by collaborating with other external players. Many MNEs have established close collaborations with Chinese universities. Such collaboration will provide a training ground for Chinese researchers. Beyond collaborating with Chinese universities, MNEs in China also exchange knowledge with Chinese domestic firms through cross-licensing. As MNEs deploy more and more sophisticated R&D activities to China, there will be more knowledge spillover from MNEs to other actors in China's innovation system. And, this will enhance the country's overall innovation capacity. In addition, MNEs in China might also facilitate domestic firms' technological upgrading by providing domestic firms with the core components inside products.

Proposition 2: The R&D strategies of MNEs (e.g., Siemens) also have impacts on China's innovation system.

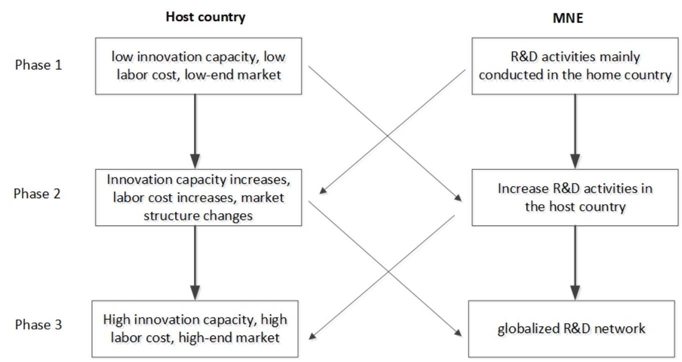


Fig. 1. The co-evolution of MNEs and host-country environments

IV. Methods

We adopted the case-study method in this research [24][25]. The investigation includes 19 in-depth interviews, 2 workshops, and 1 factory visit. The interviews were conducted in a "semi-structured" fashion, which means that they were guided by questions with open ends. The investigation covers Siemens' R&D activities regarding industrial robots, both in China and in other parts of the world. The Chinese part of the investigation was conducted by the research team at Tsinghua University, whereas the global part was conducted by team members from University of Oxford and Boston University. The interviews were recorded and transcribed if permitted. Otherwise, extensive field notes were taken. A list of the interviews completed is shown in Table 1.

In addition, we also collected and analyzed archival data.

V. Results

A. Background of the industry

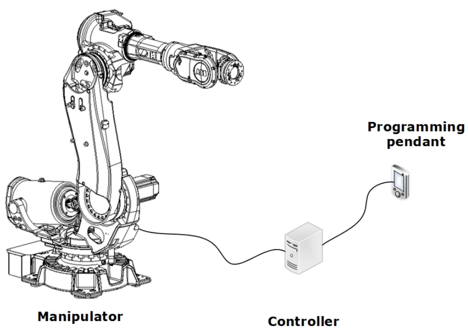
1) What is an "industrial robot": An "industrial robot" is a robotic arm used in factory-environment for completing certain tasks. Unlike "service robots" that often mimic human appearance (e.g. HITACHI's EMIEW3), "industrial robots" look nothing like human-beings. An "industrial robot" mainly consists of a "manipulator", a "controller", and a "programming pendant". The "manipulator" is the body of an industrial robot that physically performs the tasks, the "controller" is a component that controls the movement of the manipulator, and the "programming pendant" is the terminal that teaches the manipulator how to behave [26].

The complexity of an "industrial robot" is determined by the number of axes. Low-end "industrial robots" tend to have

Table 1. List of interviews completed

No.	Interviewee	Position	Location	Date
1	Zhuo, Yue	director of Research Group Automation & Control, Siemens Corporate Technology China	Beijing	1 August 2017
2	Chen, Qixiao	head of Technology & Innovation Management, Siemens Corporate Technology China	Beijing	1 August 2017
3	Zhu, Feng	Manager of CT Suzhou	Suzhou	7 August 2017
4	Zhang, Ming	Manager of Siemens Wuxi Innovation Center	Wuxi	8 August 2017
5	Li, Ming	Head of Research Group, Product Automation Engineering	Shanghai	9 August 2017
6	Peter Mertens	head of Research, Siemens Corporate Technology China	Beijing	15 August 2017
7	Lothar Herrmann	CEO Siemens Greater China	Beijing	15 August 2017
8	Chen Yangqiu	CEO of Hitachi (China) Research & Development Co., Ltd	Beijing	26 July, 2017
9	Deng Lingling	Government Affairs Manager	Shanghai	9 August 2017
10	Gu Zhijun	General Manager of KAI BO DI Robot	Wuxi	8 August 2017
11	Thomas Schott	former head of Automation Solutions, Factory Automation business unit, Siemens Digital Factory Division	Beijing	7 December 2017
12	Paul Beasley	Professor, Head of R&D UK; Siemens UK at the STFC at the RAL	Europe	30 October 2017
13	Jan Kratzer	Professor, Head of the Department of Entrepreneurship and Innovation Management, TU Berlin, Germany	Europe	1 November 2017
14	Natascha Eckert	Dr., Head of University Relations, Siemens AG, Headquarters in Munich, Germany	Europe	3 November 2017
15	Lutao Ning	Dr., Reader in International Business, at Queen Mary, University of London	Europe	20 November 2017
16	Yongjiang Shi	Dr., University Lecturer, Research Director of Centre for International Manufacturing (CIM), University of Cambridge	Europe	21 November 2017
17	Shuanping Dai	Junior Professor, University of Duisburg-Essen, Germany	Europe	22 November 2017
18	Tobias ten Brink	Professor of Chinese Society and Business, Vice-Director of the China Global Centre at Jacobs University, Germany	Europe	5 December 2017
19	Dr. Forrest Rogers-Marcovitz	Robotics Engineer, Rethink Robotics, Boston	US	28 September 2017

less axes (e.g., 3-4 axes), whereas high-end "industrial robots" tend to have more axes (e.g., 6 axes).



Source: drawn based on information from ABB and Yaskawa websites

Fig. 2. The typical appearance of an industrial robot

2) The market and key players: The market of industrial robot has witnessed rapid growth in the past decade. According to data from International Federation of Robotics (IFR), the worldwide annual supply of industrial robots has increased from 81,000 in 2003 to 254,000 in 2015.

The leading players in this market include Kuka, ABB, Fanuc, and Yaskawa, which are the so-called "Big Four". Kuka is a robot maker that originated in Germany. It entered the Chinese market in 1986 [27] and it captured 10.3% of the Chinese market share in 2015 [28]. However, in 2017, Kuka was acquired by a Chinese company, Midea group.

ABB is a multinational enterprise that came out of the merger of two well-known European electrical engineering companies, a Swedish companied called ASEA and a Swiss company called BBC. ABB entered Chinese market in 1994 [27] and it captured 14.6% of the Chinese market in 2015

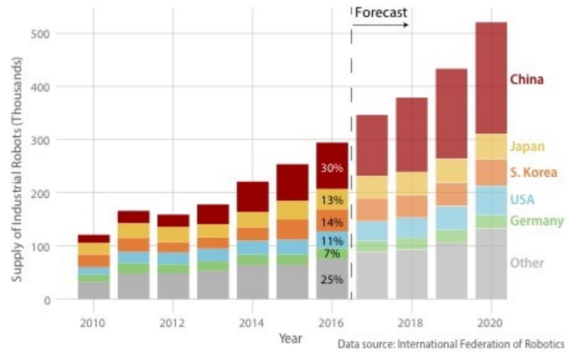


Fig. 3. Annual shipments of industrial robots by market

[28]. In 2015, ABB established a wholly owned subsidiary, ABB Robotics (Zhuhai) Ltd in Zhuhai, which was a strategic move toward the Chinese industrial robot market.

Fanuc is a Japanese multinational that entered China in 1997 by establishing a joint venture with Shanghai Electric Group [27]. In 2015, Fanuc captured 15.5% of the Chinese market share [28].

Yaskawa is also a Japanese company that entered China in 1999 [27]. In 2015, Yaskawa expanded its factory in Changshu (Jiangsu province). After this expansion, Yaskawa can produce 1000 units of robots per month. Its Chinese market share in 2015 was 12.1%.

Given the huge market potential and strong government support, many domestic firms also entered this industry. Some firms mainly focus on the components of industrial robots, such as Nantong zhenkang machinery, SHKE, Leaderdrive, HENGFENGTAI, GOOGOLTECH, Sciyon, and so on. In contrast, other firms focus more on the integrated robots, such as SIASUN, ESTUN, EFFORT, TRIOWIN, GSK, QUICK ELECTRONIC, Pt-technologies, and so on [27]. Among these domestic players, Sciyon, ESTUN, and SIASUN already evolved into listed companies which obtained relatively high revenues from the industrial robot business.

B. Siemens and its "industrial robot" project

1) Factors behind Siemens industrial robot project in China: Generally speaking, a combination of external and internal factors leads to the fact that the "industrial robot" project was "born" in China. The changing host-country environments (e.g., market/technological/policy environments) are the external factors behind Siemens' industrial robot project, whereas the insights of senior management team of Siemens China, the competences of the local R&D team, and the support from board members are the internal factors that lead to the success of the project.

a) External factors: The changing host-country environments are the external factors behind the Siemens industrial robot project. Here, the host-country environments consist of policy environments, market environments, and technological environments.

The changing policy environment: The changing policy environment mainly has two implications on Siemens industrial robot project. First, it provides incentives for Siemens to increase its R&D activities in China. Second, it guides more firms (including domestic firms) to shift their attentions to the industrial robot sector.

According to China's High and New-Technology Enterprise (HNTE) Program published in 2008, firms that are qualified as HNTE can enjoy a 15% tax rate, which is much lower than the standard 25% tax rate. To be qualified as HNTE, firms need to ensure that they will invest certain proportion of sales into R&D [1]. For example, for firms whose sales was higher than 200 million RMB in a previous year, they should invest at least 3% of sales into R&D. This means that, for a company with huge sales revenue from the Chinese market (e.g., Siemens), it must invest a lot for R&D activities in China.

> "*Well, in September 2015, we were the first to propose such a project. Luckily, at the end of 2015, Siemens China decided to increase it R&D (investments) significantly in China because of the HNTE (High and New-Technology Enterprise) program... At that time, the project was 'money-driven'. Siemens decided to strengthen its R&D forces in China, so we need to choose some new topics to do.*" — Zhuo Yue, director of Research Group Automation & Control, Siemens Corporate Technology China

In addition, the Chinese government sent strong signals to companies through a series of policies/plans that industrial robot is a promising field. For example, in March 2012, the Ministry of Science and Technology released "Intelligent manufacturing technology development 12th Five-Year special planning", which called for further development of industrial robots. In July 2012, the State Council published "Development Plan of Strategic Emerging Industries in the Twelfth Five-Year period", which again highlighted the importance of developing autonomous control system, industrial robots, and related components. In May 2015, the State Council published "Made in China 2025", which is a strategic plan about transforming China into a leading manufacturing country. In this plan, "High-end CNC machine tools and industrial robots" is listed as one of the ten fields that deserve further development.

The changing market environments: The labor cost in China has been rapidly increasing in the past decade. Meanwhile, the cost of industrial robots has been decreasing as the technology becomes mature. Given the rising labor cost, more and more Chinese manufacturers are considering replacing their labor forces with industrial robots. This creates huge demand for industrial robots.

> "*China is already the biggest market for robots. And, China is the fastest growing market for robots. And, in China, there is strong government support for robotics companies and R&D activities. This growth will even be stronger in future. And, many of the companies that make robots are ready to buy this electrical equipment and controllers from third party companies.*" — Peter Mertens, Head of Research, Siemens Corporate Technology China

Although many domestic firms entered this industry, they have weak technological capabilities. To make robots, these firms need a key component, the "brain" of an industrial robot which is called the "controller". However, the technological capabilities of these domestic firms are not sufficient for developing robot controllers, especially for making high-end industrial robots.

> "*Most of the domestic OEMs are buying controllers from foreign firms or making low-end robots such as 4 axes robots. The controllers for 6 axes robots are still under the control of foreign multinationals. We think this is an opportunity for us. We have the brand and the leading position in the field of automation. There are often partners telling us they want to buy robot controllers and asking why Siemens is not making robot (controllers)... the opportunity is good... there is strong market demand... and at the same time, Siemens was increasing R&D investment...we made a feasibility analysis report... and it was approved.*" — Zhuo Yue, director of Research Group Automation & Control, Siemens Corporate Technology China

These Chinese firms often cannot buy robot controllers from the incumbents such as the "Big Four", because the "Big Four" are producing industrial robots themselves. Thus, they are reluctant to sell controllers to arm their competitors. Siemens realized this unique market opportunity in China. Unlike the "Big Four", Siemens did not make industrial robots before, but Siemens already realized that it must have some offering in the robotics area, so that it could catch the technology trends. Given its existing technological capabilities in the field of controls and electrical equipment, Siemens formulated a unique strategy for entering the industrial robot industry, which is to offer robotic control drive package to Chinese OEMs.

The changing technological environments: Although many people might still have the impression that Siemens is a hardware company, this is not necessarily true nowadays. Many years ago, Siemens started its digital transformation. Now, "digitalization", "electrification", and "automation" are three core areas of Siemens business. The recent development of digital technologies, such as IoT and Big Data, facilitated the development of industrial robots. In fact, the industrial robot project is a software project. The research team at Siemens Corporate Technology (CT) China developed the robot controller software based on the standard Siemens hardware. The robot solution package developed by Siemens would allow users or third parties to add advanced functions to their robots. This parallels what happens in the mobile phone market, in which Chinese domestic firms produce mobile phones based on the platform and core components provided by foreign MNEs (e.g., Android by Google and chips by Qualcomm).

[1] There are other criteria (e.g., patents) which are not mentioned here

The changing technological environment (e.g., mainly the development of digital technologies) made Siemens' "eco-system" approach to entering the industrial robot industry more attractive and more feasible.

> *"We are making a system... just making a robot or just providing information security is not very meaningful. We are making a system, which is Siemens' integrated 'Industrial 4.0' solution. That includes Internet of Things, robots, information security, data analysis... I think they are a whole, which can be sold to customers as value-added services in one package. Simply making one thing will be very difficult nowadays... so we provide an integrated solution."* — Zhu Feng, Manager of Siemens CT Suzhou

b) Internal factors: The changing host-country environments offered Siemens an opportunity to enter the industrial robot industry. However, it also requires a set of internal factors for Siemens to seize the opportunity. In fact, agent and organizational capabilities are extremely important for a firm to adapt to the changing environments [29]. To be more specific, the insights of senior managers of Siemens China, the competences of the local research team, and the support from board members are important internal factors that lead to the success of the industrial robot project.

The competences of the research team: The local team is the right team to conduct the industrial robot project. The team leader Dr. Zhuo Yue was Siemens "Inventor of the Year" in 2014, who has a track record of outstanding research at Siemens CT. The local team members had already proved in other areas that they have enough competences to carry out the industrial robot controller project.

> *" (the local team members do) not over promise, but do what they promise."* — Peter Mertens, Head of Research, Siemens CT China

The insights of senior managers: The insights and actions of the senior management team also played an important role behind the success of the Siemens industrial robot project. Here, the senior management team includes Lothar Herrmann (CEO Siemens Greater China), Zhu, Xiao Xun (head of Siemens Corporate Technology China), Peter Mertens (head of Research, Siemens Corporate Technology China), Zhuo, Yue (director of Research Group Automation & Control, Siemens Corporate Technology China), Chen, Qi Xiao (head of Technology & Innovation Management, Siemens Corporate Technology China), among others.

Siemens is well recognized in the domain of industrial automation, and the senior management team at Siemens China realized the fast-growing industrial robot market, and identified the market needs from local industrial robot OEMs (e.g., advanced controller which can be seamlessly integrated into Siemens' automation solution with a competitive price level).

So, the CEO Siemens Greater China, Lothar Herrmann, raised the idea of "industrial robotics" to Siemens AG.

> *"When I raised the idea of industrial robotics to Siemens AG, the board asked me, 'Do you want to become a robot maker?' I said, 'No, but we have already had strong setup in industrial automation ecosystem, and there should be a way to add value to the robot OEMs as a key component supplier.' "* — Lothar Herrmann, CEO Siemens Greater China

The support from board members: At the beginning, the management team from Siemens China could not convince the business units with their idea of "industrial robots", but they successfully convinced the board members. The board members' support was extremely valuable for this project, because the board members are really important for ensuring that necessary resources and money can flow into such a project.

With all the agent/organizational capabilities above (e.g., capable local research team, proactive senior management team, and supporting board members), Siemens successfully seized the opportunities offered by the changing host-country environments. The following section further elaborates on the co-evolutionary process behind the Siemens industrial robot project.

2) The co-evolutionary process: As part of China's innovation system, Siemens has established collaborations with 87 Chinese universities and education institutes. Between 2011 and 2015, Siemens invested 711 million RMB in terms of cash, software, and hardware to support the development of education in China. Following the "Made in China 2025" national strategy, Siemens renewed the Memorandum of Understanding with Ministry of Education for enhancing the collaborations with Chinese partners in the area of talent cultivation. Over the past decades, Siemens has co-evolved with China's innovation system. And, such co-evolutionary process can be divided into three phases.

a) Phase I (1872-1949): Before the founding of the People's Republic of China (PRC), China had weak technological capabilities. Its modernization started with importing foreign products and technologies. Since China's national innovation system had not been developed back then, the education level of Chinese labor was quite low. At that time, China was mainly a market for foreign multinationals to sell their existing products.

b) Phase II (1985-1998): After China re-opened its door in 1980s, the country realized that it was still lagging behind western countries in terms of technological capabilities. However, PRC had a strong commitment to developing indigenous technological capabilities. It used different policy tools (e.g., tax incentives) to attract MNEs to make FDI in China, since FDI could generate "knowledge spillover" [23] within China's national innovation system [30].

After taking roots through ups and downs in China over decades, Siemens expanded cooperation to support China's opening-up and modernization since 1980s. It was a very pragmatic approach to see the opening of the market. At that time, Siemens operations in China were mainly service-oriented, not innovation-oriented.

1994 marked the founding of Siemens Ltd., China in Beijing, consolidating Siemens' rapidly growing operations and investment in China. At that time, it was the first holding company formed by a foreign company in China. It soon became the corporate headquarters for Siemens in China, focusing on the management, integration and promotion of business activities. With establishment of a broad local manufacturing base in China, Siemens also transferred many innovative technologies and substantial management know-how to local actors in the process of localization, which increased local added-value.

It is also during this period that the company, instead of bringing foreign products to China, started to develop products "in China" and "for China". At that time, Siemens R&D activities in China were more focused on the "D" (development) side instead of the "R" (research) side.

c) Phase III (1998-2016): Since 2000s, China has been transforming itself from an "imitator" to an "innovator" [31]. After decades of efforts, China has developed an innovation system that supports the innovation activities of different actors within the system. For example, following decades of investments in education, China had more qualified human capital to support high-value-added activities (e.g., R&D) in China. Meanwhile, as the GDP per capital increases, the purchasing power of Chinese customers also increased. China has become one of the most important markets for foreign MNEs. The expanding "talent pool" and the growing market made China a more and more attractive place for MNEs to conduct R&D activities in China.

Siemens Corporate Technology (CT) China was initiated in 1998 and officially opened in 2006 with a mission to develop unique innovations for Siemens business in China and worldwide. Ever since then, Siemens is making constant efforts to locally design and develop the right products and solutions for the Chinese market to meet local customers' needs, integrate into local innovation eco-system, and also use China's advantages to develop technologies in the country for global application. In response to China's national strategy of "innovation-driven development", Siemens also forms strategic partnership with local innovative medium-sized, small and micro enterprises to initiate pilot projects, and joins hands with local companies to establish innovation platforms, aiming to achieve win-win with local governments and partners. Siemens is building an innovation eco-system to support China with its transformation to digitalization.

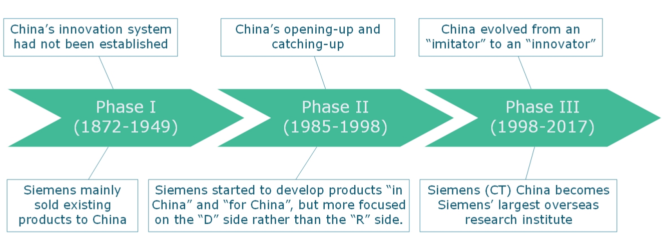


Fig. 4. Siemens and its 140 years of history in China

Although Siemens is a company with a long history of innovation activities, it is not until recently that the company started to move into the field of industrial robots. The "industrial robot" project was initiated by Siemens China. And, Siemens (CT) China is playing a leading role in this research project. The more detailed co-evolutionary process behind the Siemens industrial robot project is described below:

First, the changing technological trends (e.g., digital transformation of the manufacturing industry) in the world and the changing market conditions in China (e.g., rising labor costs) indicate that there will be huge demand for industrial robots in China. Second, many domestic firms captured this signal and entered the industrial robot industry. However, they do not have sufficient technological capabilities to produce the core components of (advanced) industrial robots. They would like to purchase core components such as robot controllers from established MNEs. Third, the senior management team at Siemens China and CT China perceived the unique opportunity offered by the host-country environments. The local research team at Siemens CT China conducted feasibility analyses. And the results of the feasibility analyses show that conducting the industrial robot project in China is viable and important. Fourth, senior managers of Siemens China proposed the idea to Siemens AG managing board and the headquarter of the corresponding Business Unit (Factory Automation FA). Although the senior management team of Siemens China could not convince the Business Unit at the beginning, they successfully convinced the managing board to support the project. With supports from the board members, Siemens China kicked-off the program of Siemens China Innovation Center in early 2016, which is a remarkable milestone to strategically initiate R&D topics from China and conduct the R&D activities in China. And, the project of "Robotics" was prioritized as a major topic. Fifth, CT China worked closely with Business Units and local academic partners to realize the idea and made an alpha version prototype within one year. In 2016 and the first half of 2017, CT was working on the robot controller project with its own resources. After demonstrating the prototype in the headquarter, Siemens China received more and more attentions from Siemens AG managing board as well as the headquarter of the corresponding Business Unit (Factory Automation FA), and most of the senior managers would like to pay a visit to CT China's robotics lab when they had business trips in Beijing. Sixth, after rounds of technical assessment and strategic alignment, the headquarter made the business decision and took the technology roadmap developed by Siemens China. In April 2017, the business unit decided to take over the project. So, from the next fiscal year (starting from October 2017), the business unit will continue the development work initiated by CT China. And, the business unit will eventually develop the robot controller (prototype) into products with its own R&D resources. Because of the outstanding work done by local organization, "Robotics" is selected as one of the Corporate Core Technologies — which are guidelines of Siemens' global innovation focuses, and the only one led by Siemens China organization.

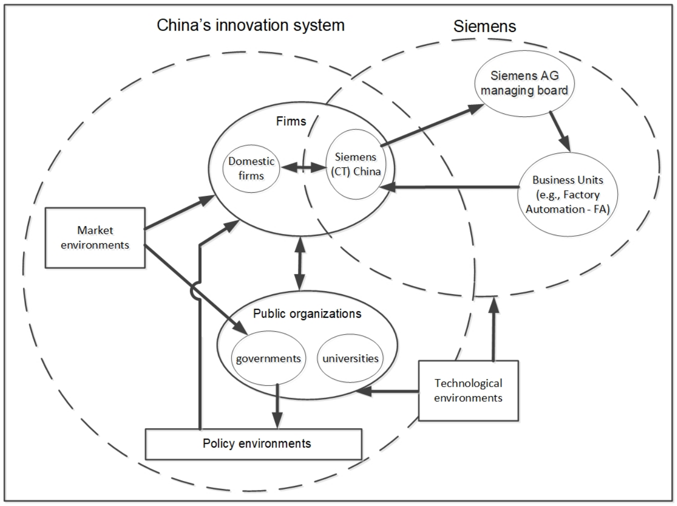


Fig. 5. The co-evolutionary process behind the industrial robot project

3) Siemens strategy towards industrial robot: What we would like to emphasize is Siemens' unique "ecosystem" approach to entering the industrial robot market. In China, Siemens is developing robotic controller as a full package, which does not only include the controller itself, but also includes the software, the drive, the electric part of the robot, plus the engineering software. All these elements are integrated into the full Siemens automation frame.

In this sense, Siemens robotic products have one unique advantage: Siemens does not only provide the controller, but it also provides all the automation equipment around it. It is much easier for its customers to integrate Siemens robotic solutions into their complete manufacturing system. For example, one big part of it is the engineering software for robotic movement. Siemens has a complete offering of engineering software for its customers. The portfolio of the Siemens robotics team is not only about the controller, but also about the integration of the controller with other Siemens software.

As a next step, Siemens will develop advanced functions such as force feedback control, safety functions, human-robotic interactions on top of its robotic offering. Eventually, Siemens aims to develop an eco-system that involves third parties to develop solutions based on Siemens products.

Since robotic technologies have been becoming increasingly important worldwide, Siemens' "ecosystem" approach might help Siemens to expand its connections with other partners. For example, when other companies buy robotic products from Siemens, they might also buy other equipment together. It will be an advantage for customers if they buy everything from Siemens because of the seamless integration between Siemens' robotic offerings and its other products.

VI. Conclusions

The research shows that Siemens' innovation about industrial robots is an outcome of the co-evolutionary process. On the one hand, the evolution of China's innovation systems changes the host-country environments facing foreign MNEs, which subsequently changes the R&D strategies of MNEs in China. On the other hand, the changing R&D strategies of MNEs also have impacts on China's innovation system. For example, in the case of Siemens industrial robot project, the core components provided by Siemens will allow other domestic robot makers to produce more advanced robots, so that they might effectively compete with the incumbents in this industry.

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