# Global Innovation Hotspots

Innovation ecosystems and catching-up in developing countries: Evidence from Shenzhen

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# Global Innovation Hotspots

Innovation ecosystems and catching-up in developing countries: Evidence from Shenzhen

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## Summary

During the past 40 years, Shenzhen has risen from a fishing village into a globally leading innovation hotspot. What drives such remarkable growth? Is there a “Shenzhen model” for technological catch-up that is different from the classical “Silicon Valley model”? What kind of policy lessons can Shenzhen offer to developing countries and lag-behind regions? Based on international patent and scientific publication data, this report classifies Shenzhen’s technological trajectory and catch-up process into three stages: 1) accessing advanced technology by participating in the Global Production Networks (GPNs) and Global Value Chains (GVCs), 2) accumulating technological knowledge and enhancing absorptive capability through imitation and 3) achieving indigenous innovation. We interpret this remarkable catch-up process from the perspective of 1) technological specialization, 2) the local innovation ecosystem and 3) its embeddedness into the Global Innovation Networks (GINs). The last part summarizes Shenzhen’s policy lessons in fostering innovation-based economic growth in developing countries and areas.



**Keywords:** Innovation, Specialization, Ecosystem, Network, Shenzhen, Patent

# 1. Introduction

“Politicians used to promise a chicken in every pot. Today, it’s a Silicon Valley in every state,” says Adam Thierer (2021), depicting the iconic role of Silicon Valley as a globally leading innovation hotspot and the worldwide enthusiasm in recreating its tech clusters. However, recently, both policymakers and scholars began to realize that most of such top-down attempts have failed (Kerr and Robert-Nicoud, 2019; Taylor, 2016).

This report presents a successful case from a developing country – Shenzhen, which is renowned as China’s Silicon Valley. In 1980, Shenzhen, as its name describes – “deep drain near rice paddies” – was just a fishing village in Guangdong province, neighboring Hong Kong, with fewer than 33,000 residents. After 40 years of high-speed growth, it has become a globally leading megapolis, with 17.56 million citizens in 2020. With an annual growth rate of 20.7 percent, Shenzhen’s GDP has risen to 429 billion US dollars in 2020, which is nearly 10,000 times the GDP of 1980,[1] surpassing the GDP of Ireland (ranked the 29th country in the world by GDP) to become one of the top five cities in Asia (World Bank, 2010). It has been rated as the fourth-most competitive city globally and number one in China (UN-Habitat, 2020). The astonishing rise of Shenzhen, in the words of former Chinese president Hu Jintao, is “a miracle of industrialization, urbanization and modernization in history” (Hong, 2010).

What explains this spectacular growth? Innovation certainly played a major role. During the last decades, Shenzhen has contributed to more than one third of China’s Patent Cooperation Treaty (PCT) applications and, with a total of 20,200 PCT applications in 2020, Shenzhen is the fourth-greatest source of PCT filings by number, right after the People’s Republic of China, the United States of America and Japan (WIPO, 2021). Shenzhen and neighboring Hong Kong form the second-largest Global Innovation Hotspot (WIPO, 2019). Meanwhile, Shenzhen has also become a world capital for high-tech entrepreneurs. Several entrepreneurial endeavors initiated in Shenzhen in the 1980s and 1990s have become the base for world-class technological giants, such as Huawei, ZTE, Tencent, BYD and BGI group. In addition to incubating plenty of fast-growing start-ups, including the world’s largest drone-maker DJI and the “king of African mobile phones” Tecno, this innovation entrepreneurial hotspot has also attracted foreign start-up companies, like Revols (Canada) and Wazer (US). Many globally leading tech companies, such as Apple, Qualcomm, ARM, Airbus and so on, have set research and development (R&D) centers there (The Economist, 2017).

Shenzhen has been a pioneer and leading experimental field in economic reform and technological innovation. Therefore, the study of Shenzhen serves as a good case for

[1] www.xinhuanet.com/english/2020-09/24/c_139394442.htm.

understanding China's innovation path and future challenges. In response to the challenges caused by rising labor costs and weaker international demand, China needs to divert its economic growth from the previous factor-driven to an innovation-driven model (Wei *et al*., 2017). In the process of climbing along the ladder of the Global Value Chains (GVCs), many developing countries and regions have become locked in as foreign companies' low-end manufacturing factories have fallen into the middle-income trap. In this sense, Shenzhen has shown a clear path of how to avoid the dominance of foreign knowledge and, from being a technological follower and imitator, has upgraded to the status of an indigenous innovator.

In addition, the growth of Shenzhen's rice paddies in the 1980s into an innovation hotspot "from nowhere" (Du, 2020) could offer valuable lessons for the catch-up of lag-behind regions lacking a local supply of scientific knowledge. The traditional innovation system theory behind the "Silicon Valley model" emphasizes the crucial role of technology transfer from universities. However, lag-behind regions in developing countries usually do not possess such rich local scientific knowledge resources. Such a deficiency would not only limit a region's creativity in the early stages but would also stifle its transition into innovative regions in future. Shenzhen's overcoming of such shortages by commercializing external scientific knowledge in the early stages and building local scientific research institutes shows how a lag-behind region can promote its own innovation ecosystem by integrating into and climbing along the Global Innovation Networks (GINs).

### *1.1 Forty years of economic development*

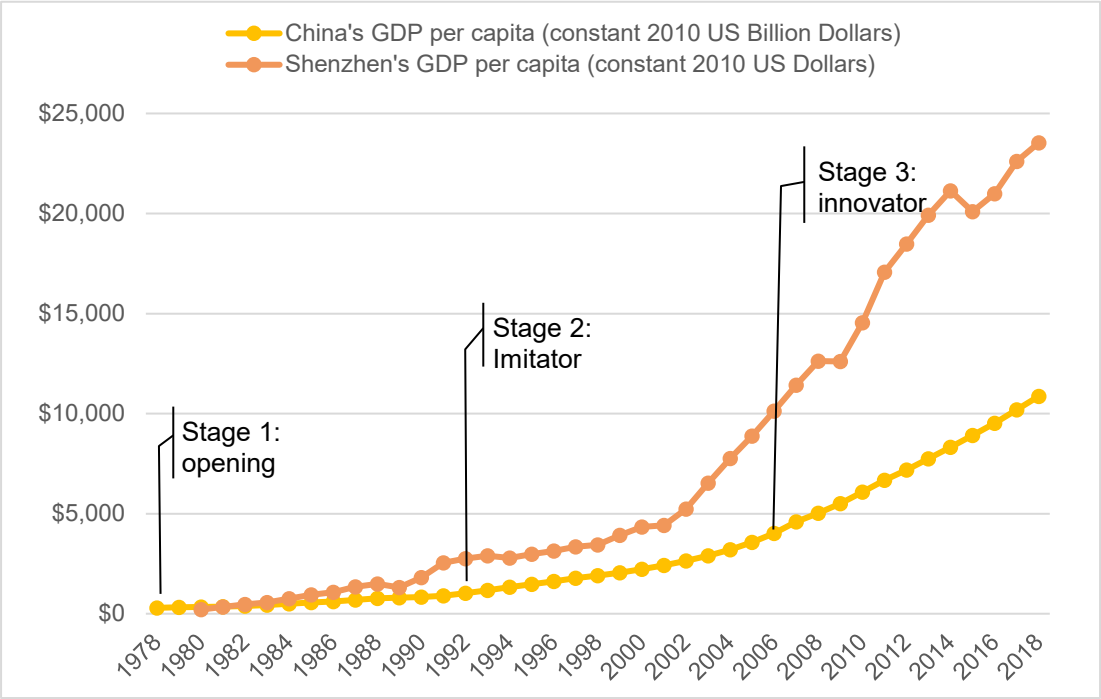
Over the past four decades, China has observed remarkable exponential growth. It has become the world's second-largest economy, with its GDP per capita having risen from 340 US dollars in 1980 to 8,254 in 2015.[2] China's economic growth has been transformed into higher investments in R&D. Since 2014, China has risen to become the second-largest R&D spender and continues to narrow its gap with the US (OECD, 2014). Although slightly lower than the average of OECD countries, China's R&D intensity has surpassed the European Union and continues to rise. This investment in innovation rendered China the world's top filer of PCT patents in 2019.[3] Many scholars even claim that the country has successfully transformed from "manufacturing China" to "innovative China" (Wei *et al*., 2017).

China's great economic growth and upgrading have historically been led by its two most vibrant urban centers: Beijing and Shanghai. In the past two decades, Shenzhen has considerably caught up, both in economic and innovation terms, with these two top Chinese metropoles (see Figure 1). Since 1992, it has surpassed these two cities in terms of GDP per capita to become the number-one city in China (Jun, 2021). In

[2] World Bank data, expressed in 2010 constant US dollars.
[3] See https://www.wipo.int/pressroom/en/articles/2020/article_0005.html

2019, its GDP per capita reached 30,000 US dollars.

***Figure 1: China's window to industrialization and development: China's and Shenzhen's GDP per capita, in constant 2010 US dollars***




*Data sources: the World Bank and the Shenzhen Statistical Yearbook*

The evolution of Shenzhen during the last 40 years is a microcosm of China's development. It also displays how successful innovation policies can contribute to the economic growth and development of a region. Shenzhen's development can be classified into the following three stages.

The first stage started roughly in the late 1970s and early 1980s. At the national level, it coincided with China's national reform and opening-up policy in 1978. Locally, it coincided with Shenzhen's authorization as the first special economic zone (SEZ) in 1980 and its upgrade to a sub-provincial city in 1981. From the establishment of the SEZ to 1985, Shenzhen went through an "era of arbitrage" in which it relied on preferential policies, that is, the price difference between the centrally planned economy and the market economy realized through price reform to gain profits. After that, this small fishing village started a rapid industrialization and urbanization process. Shenzhen transformed into an industrial district dominated by original equipment assembly (OEA) manufactures processing imported raw materials, components and necessary accessories and then re-exporting the finished products, known as "San-Lai-Yi-Bu." This implies that Shenzhen's initial participation in the GVC was through the low-end, labor-intensive manufacturing industries such as textile, toys, garments and electronics.

In 1992, the southern tour of Deng Xiaoping, chief architect of China's Open Door policy, kicked off Shenzhen's second stage of development. This historic tour included a prominent discourse in Shenzhen encouraging local policymakers to accelerate China's market-oriented reforms and opening-up process, as well as to continue to make policy experiments. In 1994, General Secretary of the Communist Party of China (CPC) Jiang Zemin visited Shenzhen and encouraged the city to "aim higher and be more innovative" (Jun, 2021).

Although the economy was still fast-growing, Shenzhen's local government realized some potential problems and challenges appeared. The first challenge was that, with many coastal regions embracing the opening-up policy and establishing their own SEZs through learning from Shenzhen's experiments, Shenzhen SEZ no longer enjoyed its previous preferential treatment. In other words, Shenzhen SEZ was no longer special. Second, as the San-Lai-Yi-Bu model is usually comprised of low value-added enterprise and heavy polluters with severe security risks, it could barely sustain Shenzhen's future economic growth. In addition, the existent infrastructure, such as narrow roads and an unstable water supply, as well as an increasingly bureaucratic government also stifled Shenzhen's further development.

After realizing these challenges, Shenzhen's local government launched a series of measures aimed at building a service-oriented government as well as improving the city's infrastructure to attract more foreign and Hong Kong, Macau and Taiwan Province of China (HMT) companies. Among these measures, the most prominent was the so-called "*Teng Long Huan Niao*" ("*Vacating the Cage for New Birds*") policy proposed by the Guangdong government. The metaphor vividly characterizes the industrial upgrading policy of relocating San-Lai-Yi-Bu enterprises to make room for Foreign Direct Investment (FDI) and high-tech companies. This policy initiated Shenzhen's systematic shift from low value-added OEA to original equipment manufacturing (OEM) activities and joint ventures with foreign and HMT companies. Meanwhile, Shenzhen's government also settled the innovation policy of promoting indigenous innovation while learning from foreign technologies. As a result, capital-intensive industries gradually phased out labor-intensive ones and became the dominant form of Shenzhen's economy. By the end of this period, Shenzhen formed a leading industrial cluster of information and communication technologies (ICTs) hosting the most comprehensive ICT supply-chain system in the world. This successful transformation from low-cost manufacturing to high value-added activities and the formation of a closely connected ICT cluster allowed Shenzhen companies to climb the ladder of GVC together.

The third and current stage started in 2006 and is characterized by a notable increase in Shenzhen's indigenous innovation. The extraordinary technological capacities built during the second period paved the way for a leap upward in the industrial transformation of Shenzhen from imitator to innovator. This echoes China's national

science and technology policy, which aimed at reducing its reliance on foreign technologies and at enhancing domestic innovation capacity from 2006 (Yang, 2016). During this stage, to capture higher returns from GVC, Shenzhen companies have embarked on Original Design Manufacturing (ODM) and even Original Brand Manufacturing (OBM) by creating their own brands and investing heavily in and conducting their own R&D activities. As a result, Shenzhen's number of high-tech enterprises has risen from a few hundred to tens of thousands within only one decade. Ten companies originating in Shenzhen – including Huawei, ZTE, Tencent, BYD and Ping An Insurance Group – are listed in the Fortune 500. This transformation has gone hand-in-hand with domestic companies in Shenzhen – led by Huawei and ZTE – starting to use intellectual property (IP) extensively to protect their inventions.

### *1.2 What drives Shenzhen's economic growth? Some identified factors*

Previous studies have identified several key complementary factors behind Shenzhen's economic growth.

The first key factor is its geographical proximity and industrial complementarity with neighboring Hong Kong (Shen, 2014). Indeed, Shenzhen and Hong Kong benefit highly from their complementarity, stimulating intense collaboration and synergy between the two cities. Hong Kong is home to numerous prestigious universities and is a global financial center. This contributes to the scientific knowledge base, a gateway to venture capital as well as international management talent, supporting the needs of Shenzhen's rising manufacturing industry. Reciprocally, Shenzhen's comprehensive manufacturing system offers an ideal location for the creativity of Hong Kong's entrepreneurs and start-ups to be realized and commercialized more rapidly and with a lower cost (Motohashi, 2018; Kerr and Robert-Nicoud, 2019).

A second crucial factor relates to the abundant supply of skilled labor (UN-Habitat, 2019). Similar to Silicon Valley, Shenzhen is a city of migrants. This means, as a young city, Shenzhen has no historical burden and no clutch of conglomerates. With Hong Kong's abundant financial capital funding creative ideas, young immigrants from other regions of China, as well as highly skilled returnees, are either attracted by large companies or explore opportunities to start their own businesses, forming a vibrant innovation and entrepreneurship ecosystem. Large companies like Huawei and Tencent have played a pivotal role in attracting and nurturing talent for both R&D and entrepreneurship, contributing to the virtuous circle and boosting the local innovation ecosystem (Motohashi, 2018).

Third, the institutions behind Shenzhen's innovation ecosystem have proven to be extraordinarily lean to foster innovation (Chen and Ogan, 2017; Lai *et al*., 2005; Tang, 2014). To support the first SEZ in China, the central government granted Shenzhen a high level of autonomy in decision-making and many preferential treatments for

attracting foreign investments, ranging from tax incentives to low-priced land-use rights and duty-free imports of raw materials (Jun, 2021; World Bank, 2010). Meanwhile, Shenzhen's local government policies and institutions have created a market-driven environment based on fair competition and rule of law in which it is easy to do business. Shenzhen's government has made constant efforts to improve its innovation ecosystem by providing efficient services for the private sector and establishing research infrastructure, R&D subsidies and venture capital mechanisms, which have attracted higher-education institutions and talents (Tang, 2016).

In addition, to overcome the constraint imposed by lacking advanced research organizations, Shenzhen has developed new types of scientific research institutes, known as "sibuxiang." Sibuxiang are incubators and institutes conducting market-driven research, combining the strengths of universities, research institutes, enterprises and governments (Wang and Wang, 2017). Starting from the Research Institute of Tsinghua University in Shenzhen, this new type of R&D institution has become a new model of R&D throughout China.

Last, several recent studies also document how FDI and Shenzhen's integration in Global Production Networks (GPNs) has fostered local enterprises' technological catch-up (Lüthje *et al*., 2013; Schaefer, 2020; Yang, 2009). As China's southern window to the world, Shenzhen's unique place connecting both the global and domestic market allows it to leverage both sides' resources to facilitate its fast industrialization process.

### *1.3 What channels Shenzhen's innovation growth?*

While the above-mentioned studies offer lots of key insights into Shenzhen's instant and successful industrialization process, that is, its evolution into a top ICT manufacturing center from stage 1 to stage 2, another question remains unclear: How could Shenzhen rise from a low-end manufacturing cluster to today's globally leading innovation hotspot during stage 3? How could a city that was a technological follower with a lack of local scientific knowledge become an indigenous innovation powerhouse? What are the main channels through which innovation has flourished in Shenzhen?

This report suggests that the second transformation is inseparable from Shenzhen's vibrant local innovation ecosystem as well as its integration into and continuous upgrading along the Global Innovation Networks (GINs). Therefore, drawing on the literature of innovation ecosystems (Frenkel and Maital, 2014; Lundvall, 2007), the Global Innovation Network (Ascani *et al*., 2020; Barnard and Chaminade, 2011; Engel and del-Palacio, 2009; OECD, 2017; WIPO, 2019), technological catch-up theory (Lee, 2019), as well as indigenous innovation theory (Fu *et al*., 2011; Yang, 2016), this report attempts to analyze Shenzhen's technological trajectory through the perspectives of 1) technological specialization, 2) the local innovation ecosystem and 3) its

embeddedness into the GIN.

To be more specific, it intends to answer the following research questions:

1) How has Shenzhen's technological trajectory evolved during the past 40 years?
2) What are the main characteristics of Shenzhen's innovation ecosystem? What is the difference with other leading innovation hotspots, such as Silicon Valley, Beijing and Shanghai? Who are the main stakeholders and how do they interact with each other? Within the local private sector, what is the role of large companies, Small and Medium Enterprises (SMEs) and start-ups? Within the public sector, what is the role of universities, research institutions and knowledge intermediaries?
3) What is the role of the innovation ecosystem and its connectivity for a city's technological catch-up and upgrading?
4) What is the role of government policy in Shenzhen's catch-up? What lessons could Shenzhen offer to the economic growth of developing countries and areas?

To answer these questions, we conducted a series of comparisons of Shenzhen with characteristics of the whole of China as well as the other two most innovative cities in China – Beijing and Shanghai.

The detailed bibliographic IP unit record data utilized in this report are extracted from the WIPO IP statistics database, EPO PATSTAT, as well as China National Intellectual Property Administration (CNIPA) databases. The scientific publication data are records from 1998 to 2017 in the Science Citation Index Expanded (SCIE) of the Web of Science operated by Clarivate Analytics. Firm's ownership information is retrieved from the Chinese Annual Survey of Industrial Enterprise (ASIE) database provided by RESSET. Other related economic data from the OECD, the World Bank and the Shenzhen Statistical Yearbook released by the Shenzhen Statistical Bureau are also used in this report.

This report is organized as follows. Section 2 gives an overview of Shenzhen's innovation growth since 1980 from the perspective of R&D inputs and performances. It is followed by sections interpreting Shenzhen's technological trajectory from the perspective of technological specialization, local innovation ecosystem and its embeddedness into the GIN, respectively. The last section concludes by discussing the results and Shenzhen's policy lessons.

# 2. An overview of Shenzhen's innovation growth

## *2.1 Shenzhen's innovation: From technological imitator to indigenous innovator*

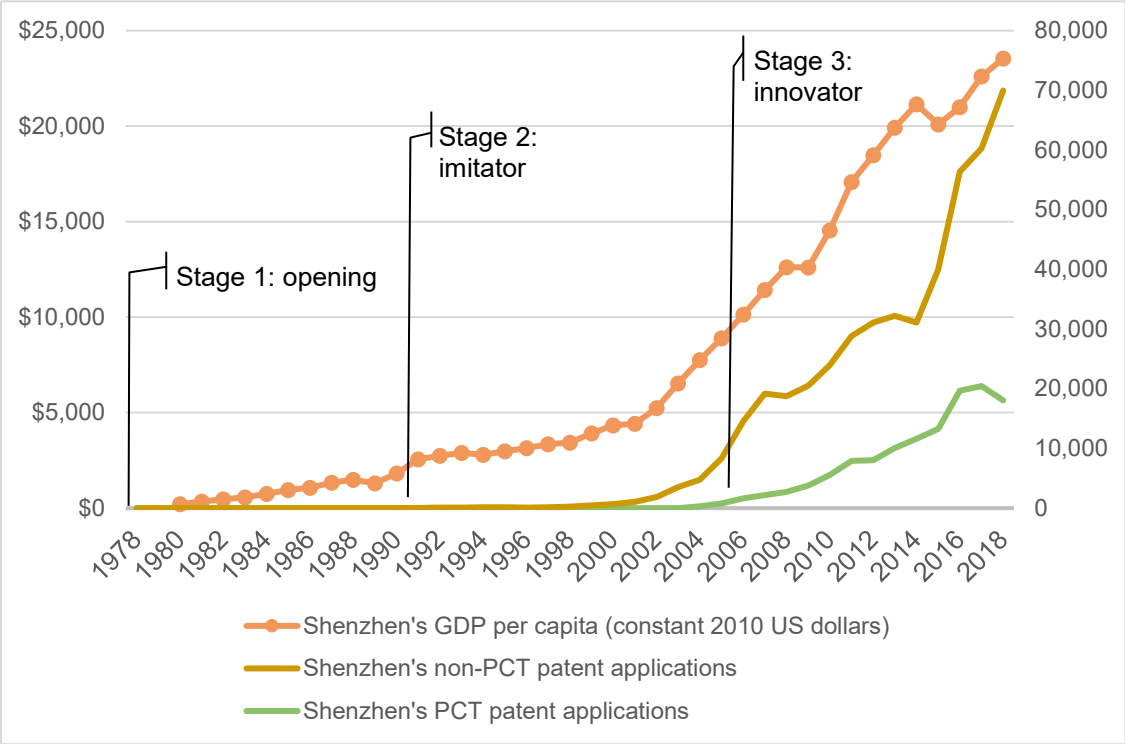
Nowadays, innovation is widely characterized as the major driver of Shenzhen's miracle. However, even an astonishingly fast-growing city like Shenzhen doesn't become an innovation hub overnight. In the early stage of Shenzhen's industrialization, there were barely any innovation activities (Figure 2). The wider participation in GVCs allowed Shenzhen companies access to some advanced foreign technologies embodied in products. Such a long-term and slow learning-by-doing process in producing for foreign and HMT enterprises brought some sporadic domestic patent filings in Shenzhen. Later, China's joining of the WTO in 2001 brought a much wider range of expose to foreign technologies and accelerated domestic enterprise's learning process. As a result, Shenzhen's technological boom started at the end of stage 2 and exploded in stage 3. In 2006, the year when GDP per capita reached 10,000 US dollars and annual domestic applications of invention patents exceeded 10,000, Shenzhen began to file more international patents, indicating this city's initial participation in the GIN.

The abbreviation of Shenzhen's name – SZ – is identical to "Shanzhai," which literally means counterfeit product made through shameless imitation with much lower quality. For a long time, as this ironic coincidence indicates, Shenzhen's production was synonymous with Shanzhai, or "copycat." Although Shanzhai was widely mocked and criticized, it marks an important or even necessary stage of the region's innovation growth.

A closer look at China's innovation history and patent quality would help us understand the value of this copycat stage.

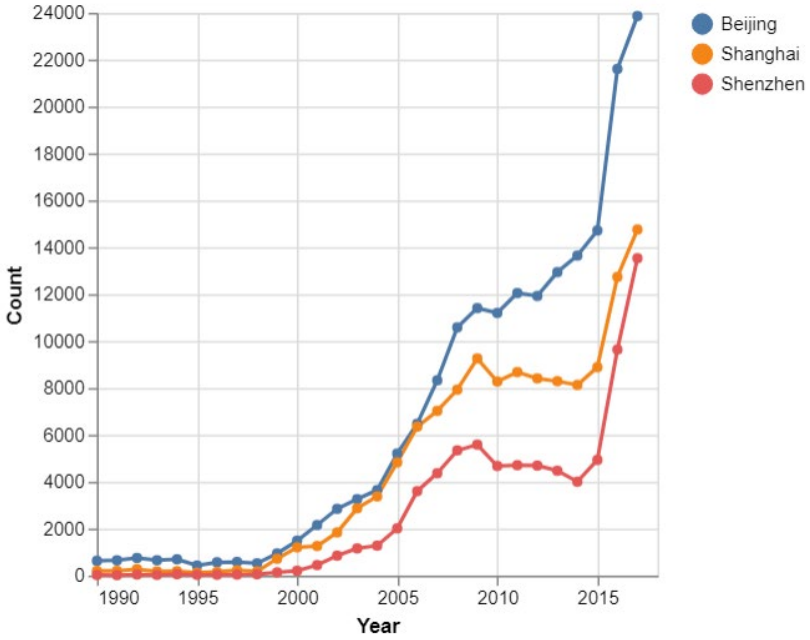
Innovation is widely accepted as the new combination of existing methods. Therefore, following the methodology proposed by Strumsky and Lobo (2015), we identified patents with high level of originality by checking all new combinations of IPC classes within the CNIPA patent database. A patent is classified as original or novel if it either contains an IPC class appearing for the first time in a patent or two IPC classes combined in the same patent for the first time. To avoid all novel patents concentrating in the early stages of a dataset, we set all IPC classes appearing in the first five years as a pool and did not count them.

***Figure 2: Evolution of Shenzhen's GDP per capita and patent applications, 1980–2018***




*Data sources: the Shenzhen Statistical Yearbook, CNIPA, WIPO-IES patent database*

***Figure 3: Evolution of top three Chinese cities' novel patents***




*Data source: CNIPA*

The evolution of China's three most innovative cities' volume of novel patents in Figure 3 reveals that all these cities' technological innovation went through a process of improving from a low level of originality to a higher level. Knowledge and skills acquired through learning-by-doing and learning-by-imitating in stage 2 prepared Shenzhen companies to become original creators themselves.

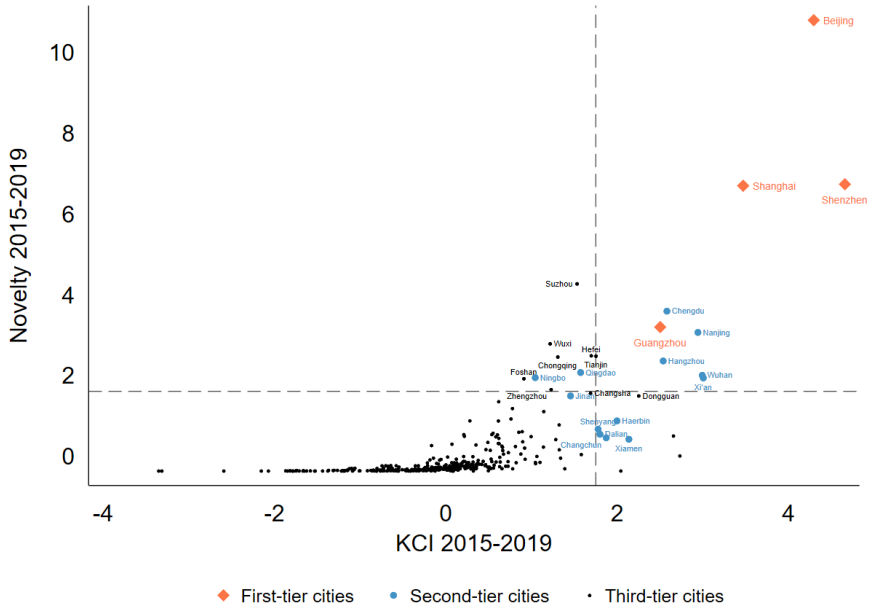
As the explosion of a large volume of highly original patents indicates, Shenzhen has evolved from a copycat to an indigenous innovator, from a technological follower to an innovation leader.

The technological complexity index (KCI) (Balland, 2017), proposed by Balland and Rigby (2017) and Hidalgo and Hausmann (2009), is another important dimension measuring a city's technological capability and comparative advantages.

Statistics shows that, starting from simple technologies in stage 2, Shenzhen companies have gradually mastered the skill of producing more complex technologies.

Finally, by combining technological novelty (on the y axis) and a complexity index (on the x axis), Figure 4 compares the relative position of all Chinese cities' technological complexity. As a result, Shenzhen ranks first in terms of technological complexity and third in terms of novelty.

***Figure 4: Chinese cities' position in technological novelty vs. complexity***




*Data source: CNIPA*

In summary, Shenzhen has transformed into an indigenous innovator from a technological follower and has formed an ICT cluster with the highest complexity among Chinese cities. How did Shenzhen realize such a transformation within two decades? The following sections will explain the change from the perspective of Shenzhen's R&D investment, technological specialization, local innovation ecosystem and embedding into the GIN.

### *2.2 Intensive R&D investment fueling Shenzhen's innovation growth*

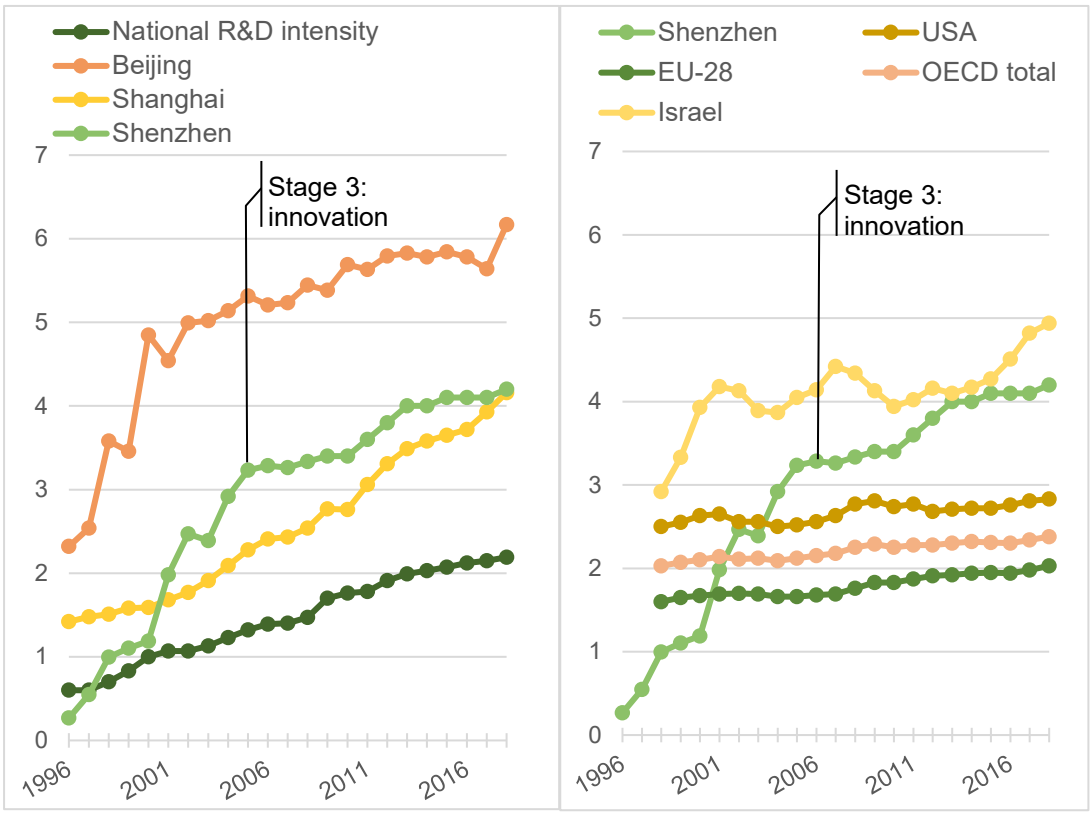
Shenzhen's outstanding innovation outputs correlate with a sizeable increase in its innovation efforts in stage 2 (Figure 5). As illustrated by the R&D/GDP ratio in the left panel, Shenzhen's innovation intensity surpassed the national average in the late 1990s. By the early 2000s, Shenzhen had become second only to Shanghai in China. In the current period, the three cities have maintained their Chinese innovation status, but Shenzhen and especially Shanghai seem to be closing some of the gap with Beijing.

Shenzhen's innovation intensity performance is outstanding even for international standards. As shown in Figure 3's right panel, Shenzhen outranks the R&D/GDP ratio of the US, the OECD countries average and the EU-28 average. It just falls short of Israel's ratio, which is among the highest in the world.

However, compared to OECD countries, China's R&D activities are dominated by downstream experimental development, with a limited share of resources being dedicated to applied research and even less for basic research (Figure 6). Shenzhen's case is even more so. Such insufficient investment in fundamental research is widely acknowledged as a bottleneck of Shenzhen's future development.

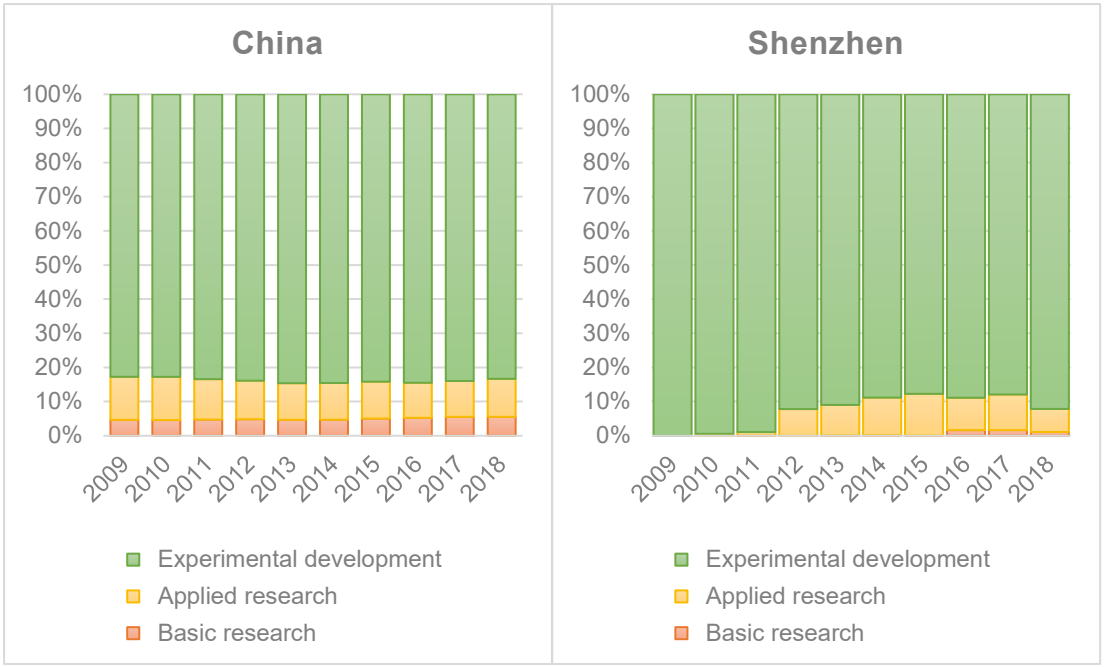
Recently, there has been a silver lining for policies promoting the fundamental basis of indigenous innovation implemented in the current period. Since 2012, Shenzhen has reported a palpable improvement in the proportion of funding dedicated to applied research and, more recently, some improvement in the proportion of investment into basic research.

***Figure 5: Shenzhen's innovation intensity: R&D expenditures/GDP, percent, selected countries and regions***




*Data sources: the World Bank's World Development Indicators: Science and technology, http://wdi.worldbank.org/table/5.13#, OECD Main Science and Technology Indicators, the Chinese Statistical Yearbook, as well as Beijing's, Shanghai's and Shenzhen's Statistical Yearbook, respectively*

***Figure 6: Structure of China and Shenzhen's R&D expenditures***



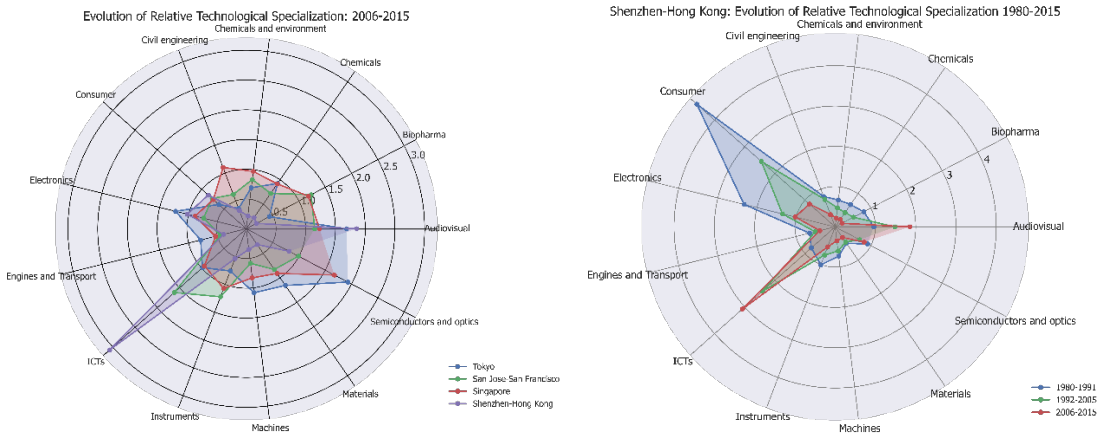

*Data Sources: the World Bank's World Development Indicators: Science and technology http://wdi.worldbank.org/table/5.13#, the Chinese Statistical Yearbook, as well as Beijing's, Shanghai's and Shenzhen's Statistical Yearbooks, respectively*

# 3 Shenzhen's technological trajectory: The formation of a globally leading ICT cluster

The relative specialization index (RSI), or Balassa index (Balassa, 1965), is widely adopted to measure a country or region's revealed technological advantage (Soete, 1987). It is calculated as the ratio between the share of the region's patenting output in one technological class and the share of the same technological class in the whole sample.

International comparison with four major Global Innovation Hotspots in RSI (Figure 7, left panel) shows that the Shenzhen-Hong Kong hotspot took a technological path quite similar to that of Silicon Valley in developing an international comparative advantage in the ICT hardware industry. The only difference is that Shenzhen's specialization in ICT is more pronounced. Meanwhile, Shenzhen is less diversified or quite weak in the pharmaceutical and semiconductor industries compared to other world-leading hotspots.

***Figure 7: Relative technological specialization of four Global Innovation Hotspots***




*Data source: WIPO-IES international patent family data*

Let us take a closer look at how Shenzhen's technological trajectory has evolved (Figure 7, right panel).

In stage 1, Shenzhen entered the GVC. During this stage, while there were barely any domestic R&D activities, Shenzhen companies started to access advanced technologies when assembling and processing for foreign and HMT companies. At that time, most cutting-edge foreign technologies were embodied in products of consumer

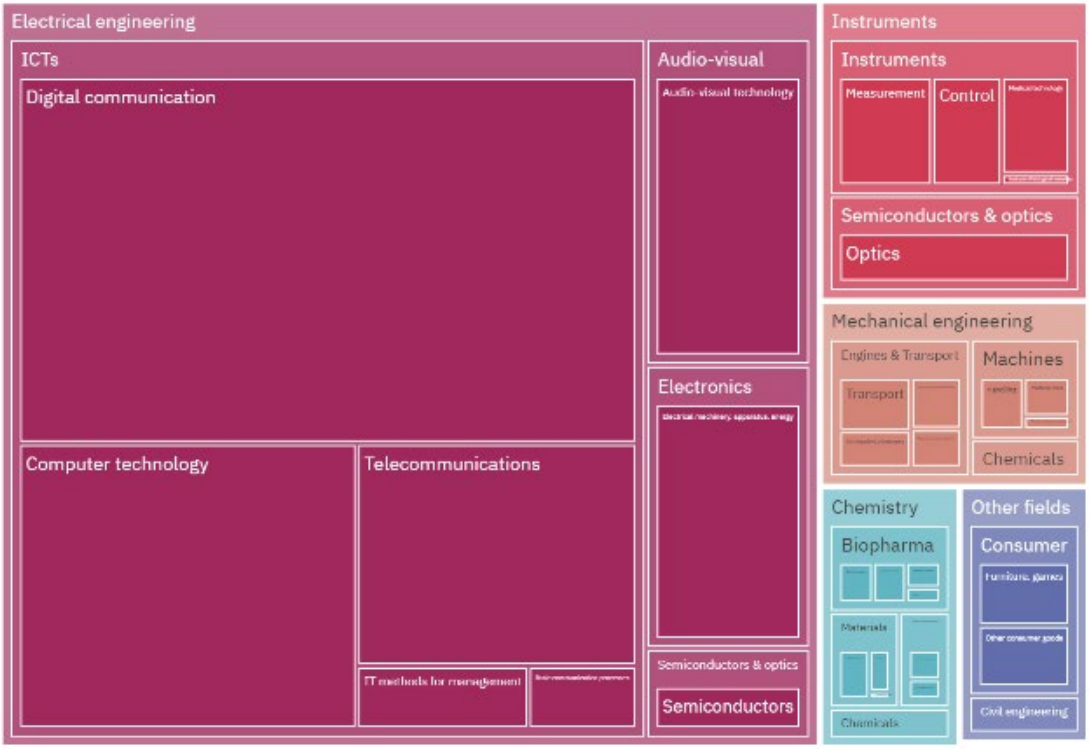
goods (e.g., home appliances and garments) and electronics.

At the end of stage 2, two new international competitive fields – ICT and audiovisual technologies – emerged in Shenzhen. A fast-paced catch-up started. As a result, Shenzhen's RSI in ICT industry even overtook Silicon Valley in stage 3, suggesting the formation of a globally competitive ICT cluster.

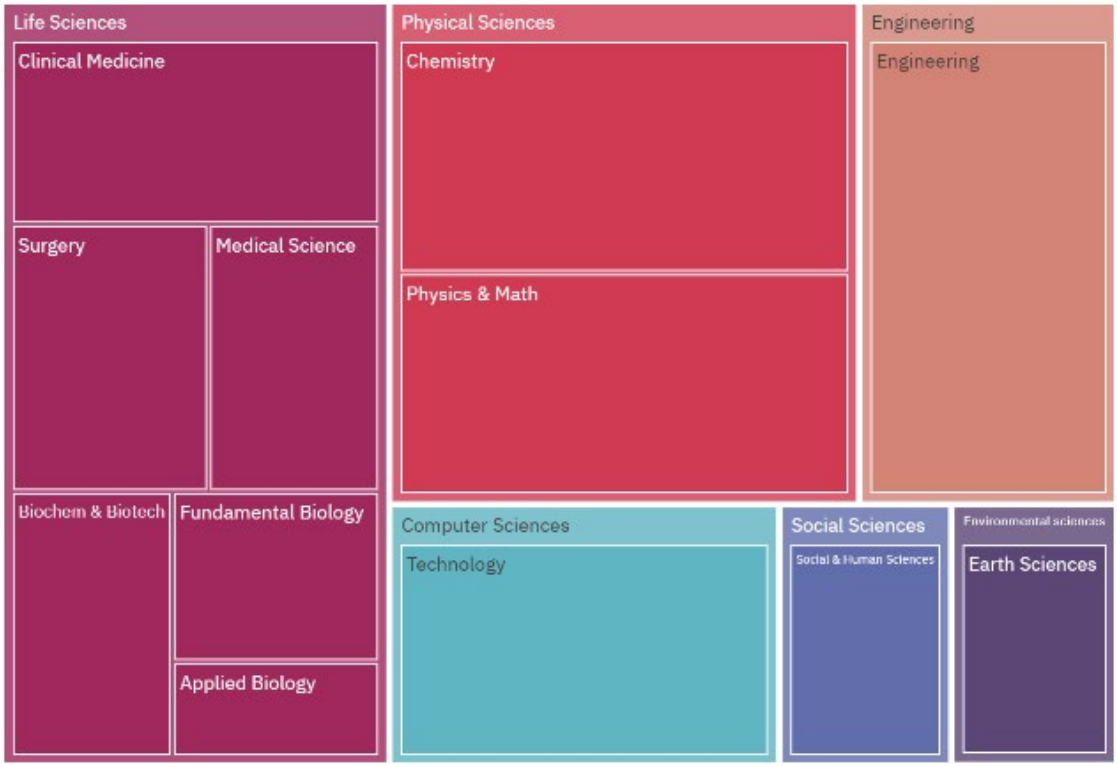
Shenzhen's technological profile further confirmed this conclusion. As indicated in the upper panel of Figure 8, Shenzhen's patenting mainly concentrated in ICT and ICT-related technologies such as instruments and optics. Shenzhen's high level of specialization in ICT technologies, together with its diversification to many ICT-related technologies, supported its upgrading to an innovation-driven economy.

However, its local scientific knowledge base, displayed in the bottom panel of Figure 8, seems to provide limited support to its technological development as well as science-based breakthrough innovations. A large portion of Shenzhen's local scientific research focuses on life sciences, chemistry and physics, while ICT-related disciplines, such as computer science and engineering, are much weaker.

***Figure 8: Shenzhen's technological and scientific profile, 1985–2015***




*Technological profile*




*Scientific profile*

*Data source: WIPO-IES international patent family data*

# 4. Shenzhen's local innovation ecosystem

What are the unique characteristics of Shenzhen's local innovation ecosystem, and how does it support Shenzhen's innovation growth? This section examines the major stakeholders within Shenzhen's innovation ecosystem and how their connectivity has shaped Shenzhen's innovation landscape.

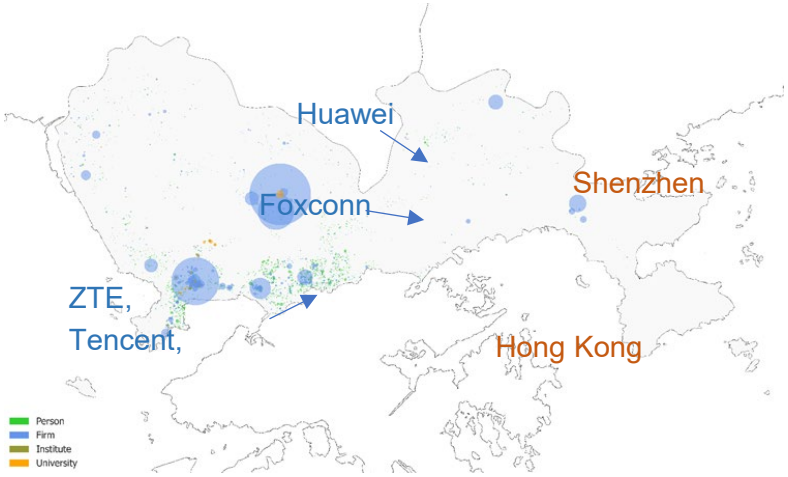
## *4.1 Which stakeholders are most active?*

### 4.1.1 Geographical distribution of stakeholders

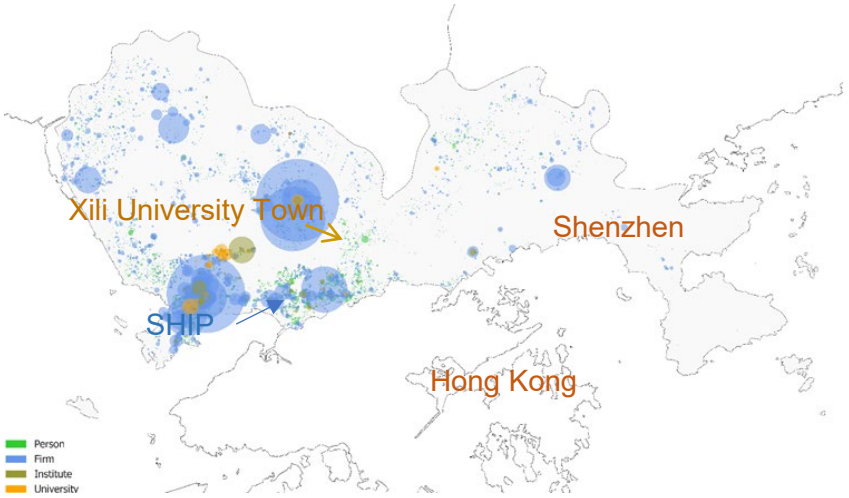
Figure 9 reveals that two major innovation centers gradually formed as innovation activities emerging around flagship companies during stage 2. The first was led by Huawei and Foxconn in Longgang district and the second was Shenzhen High-tech Industrial Park (SHIP) in Nanshan district. Established in 1996, SHIP has been one of the most successful high-tech zones in China. With just a small area of 11.5 $km^2$, SHIP has hosted more than 60 public-listed companies, such as ZTE, and has incubated 15,000 high-tech companies, including Tencent and Tecno, of which 80 percent have been SMEs.

During stage 3, while many high-tech SMEs have started to become further concentrated within the existing two innovation centers, Shenzhen's innovation activities have also expanded to peripheral districts. Surrounding Xili University Town, high-tech start-ups with cutting-edge technologies – such as Shokz, a bone-conducting earphone producer, and DOBOT, a producer of lightweight robotic arms – have grown to become global industrial leaders.

***Figure 9: Evolution of Shenzhen's innovation landscape, 1992–2015***




*Geographical distribution of Shenzhen's stakeholders during stage 2, 1992–2005*




*Geographical distribution of Shenzhen's stakeholders during stage 3, 2006–2015*

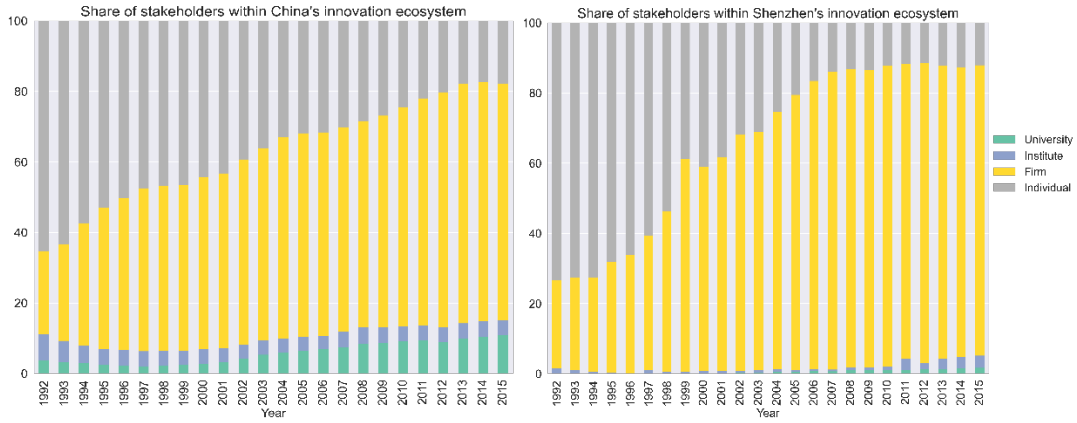
*Data source: Geocoded CNIPA patent data (Yin et al., 2020)*

### 4.1.2 Private-sector domination of Shenzhen's innovation ecosystem

As China transited from a planned economy to a market economy, its national innovation system also experienced two major transformations: the transition from being public-sector-driven to private-sector-driven and the institutionalization of innovation activities (Figure 10, left panel). In the early stages, most R&D activities were conducted by individual inventors as well as R&D institutions. But enterprises gradually became the major stakeholders of innovation (OECD, 2008). Meanwhile, the combination of both development and regulation changes led to a shrinking share of individuals. When technological improvements become costly and demand team efforts, the institutionalization of innovation occurs.

Shenzhen is the leader in such transformation, which turns out to be one of the key elements of Shenzhen's innovation miracle. As indicated by the right panel of Figure 10, Shenzhen's innovation ecosystem has been dominated by the private sector, especially privately owned companies. More than 90 percent of Shenzhen's patents are created by the private sector. Meanwhile, although Shenzhen's public sector is weak, some promising progress has occurred recently.

***Figure 10: Type of stakeholders: China and Shenzhen 1992-2015***

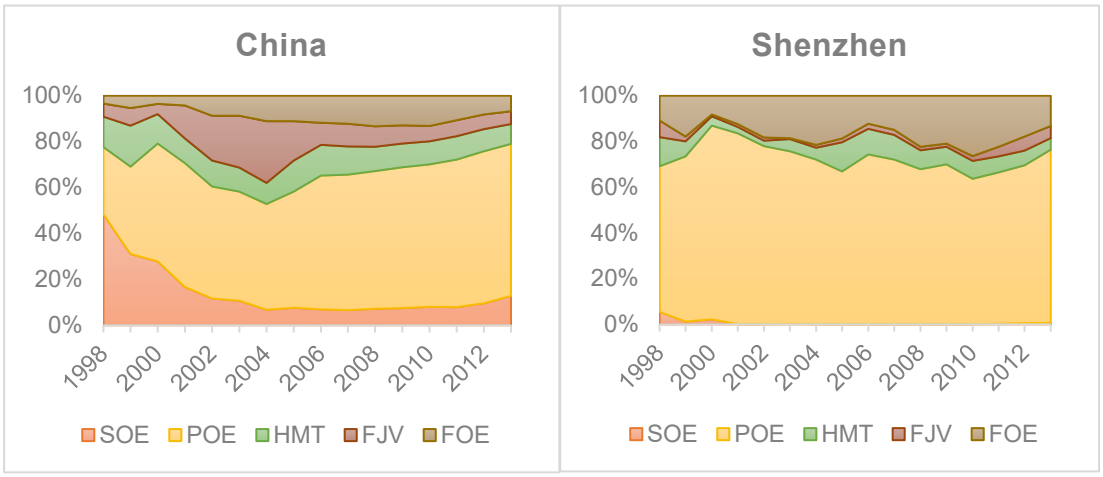



*Data source: CNIPA (Yin* et al.*, 2020)*

### 4.1.3 The rise of domestic privately owned companies and Shenzhen's innovation upgrade

Next, let us unfold Shenzhen's private sector and take a closer look at its composition. Figures 11 show the distribution of patenting activities by large and middle-sized firms in China (left panel) and Shenzhen (right panel). From 1998 to 2013, state-owned enterprises (SOE) were an important source of China's innovation, but their impact was negligible in Shenzhen. On the contrary, Shenzhen's innovation mainly came from domestic privately owned enterprises (POE). Meanwhile, although declining in its share, Shenzhen is one of the major hosts of Hong Kong-Macao-Taiwan Province of China (HMT)-owned enterprises due to its superior geographical advantage. However, HMT-owned enterprises rarely commit to innovating activities. Similarly, the share of foreign-owned enterprises (FOE) remains stable but their contribution to innovation has continued to decline since 2010. In short, domestic POEs have replaced foreign and HMT companies to become the major driver of Shenzhen's innovation upgrade.

***Figure 11: Patenting of five types of large and middle-sized firms: China and Shenzhen***




*Data source: CNIPA and ASIE*

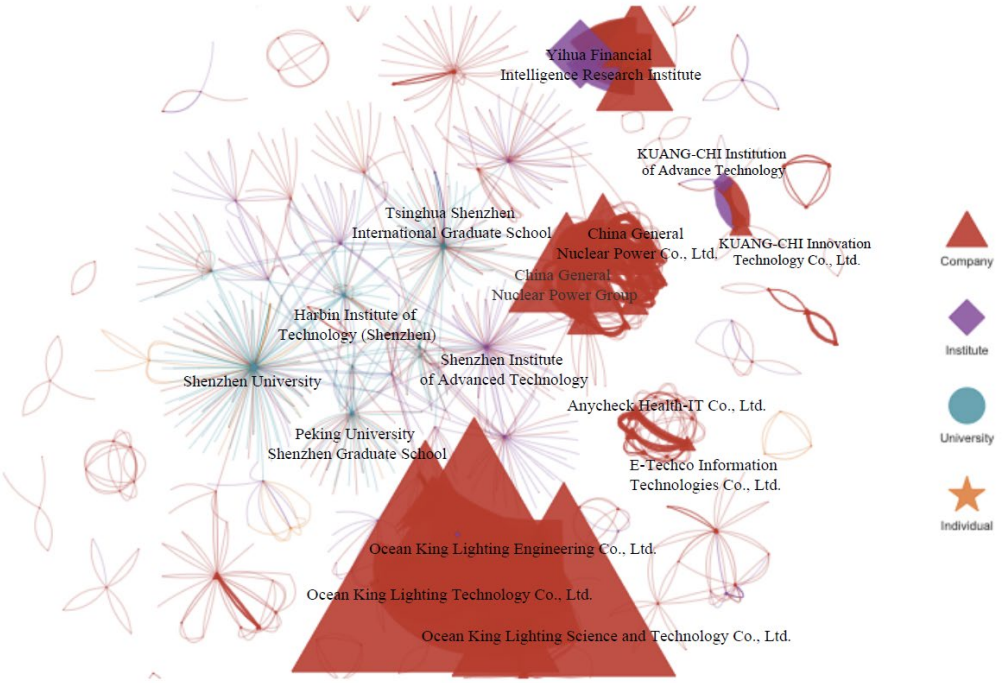
*Notes: SOEs: state-owned enterprises, POEs: privately owned enterprises, HMTs: Hong Kong-Macao-Taiwan Province of China-owned enterprises, FJVs: foreign joint ventures, FOEs: foreign-owned enterprises.*

## *4.2 Dense industrial connections strengthening the vitality of local innovation ecosystem*

What does the structure of Shenzhen's local innovation ecosystem look like? How do these major stakeholders connect to each other? Figure 12 displays the structure of Shenzhen's innovation ecosystem by visualizing an internal collaboration network among four different types of stakeholders. Different from Beijing and Shanghai, both of which contain abundant local scientific research organizations, Shenzhen's local collaborations are undertaken by local POEs. This suggests Shenzhen has formed dense local industrial connections within private sector.

In addition, the Shenzhen government's continued investment in and support for building local universities and research institutes since stage 2 has started to take effect; some joint research organizations with prestigious universities, for instance, Tsinghua Shenzhen International Graduate School (TSIGS) and Harbin Institute of Technology, Shenzhen Campus (HITSZ), have started to play an active role in local knowledge transfer.

***Figure 12: Structure of Shenzhen's local collaboration network during stage 3***




*Data source: CNIPA*

# 5. Shenzhen’s inclusion in the Global Innovation Networks

This section describes the evolution of Shenzhen’s position within the GIN from the perspective of technological collaboration and knowledge sourcing, which is measured by the backward citation of a focal city’s patents.

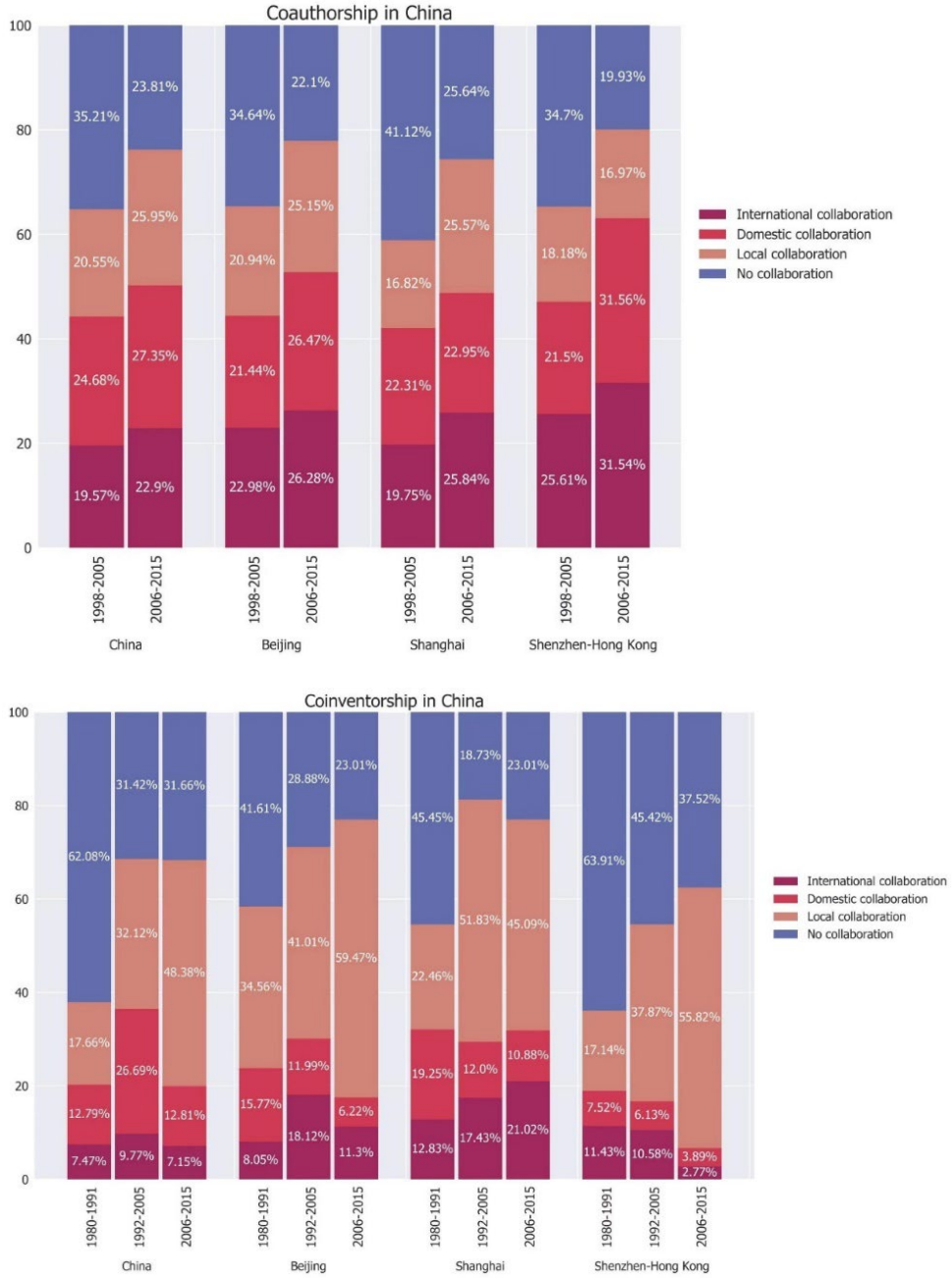
## *5.1 A new stage of climbing along the Global Innovation Networks*

During the 2000s, Shenzhen became the first Chinese cluster to enter the top 30 clusters of the Global Innovation Networks and kept on climbing steadily along the GINs. During this stage, its top collaborating cities shifted from Taipei to both Beijing and San Francisco.

Figure 13 shows the general trends in China as well as the top three cities' scientific (upper panel) and technological (lower panel) collaborations. As shown in WIPO (2019), China and the three cities enhanced their scientific collaborations at international, domestic and local levels. However, excluding Shanghai, there has been a decline in their international technological collaborations, and international collaborations have been replaced by domestic and local collaborations. Shenzhen and Beijing drive this general trend. In other words, while Shenzhen’s innovators continue to seek more external (both international and domestic) collaborations in scientific knowledge production, collaborations with local suppliers and customers have replaced international connections with foreign MNCs and have become the first collaborative choice.

There are both international and domestic factors behind this disparity. First, compared to more public and codified scientific knowledge, technological knowledge is more private and tacit in essence, thus demanding face-to-face interactions. Therefore, it is natural for the production of scientific knowledge to have a higher international and domestic collaboration intensity. Second, increased technological complexity usually demands close communications with local partners (Van der Wouden, 2020). Last but not least, cross-border collaborations are usually costly and suffer from many business risks or even political risks. Hence, as Shenzhen’s domestic companies gradually improve local innovation capabilities, they tend to choose closer and less costly knowledge partners with whom to build strong links.

***Figure 13: Type of collaboration in China and its top three cities***




*Data source: WIPO-IES international patent family data*

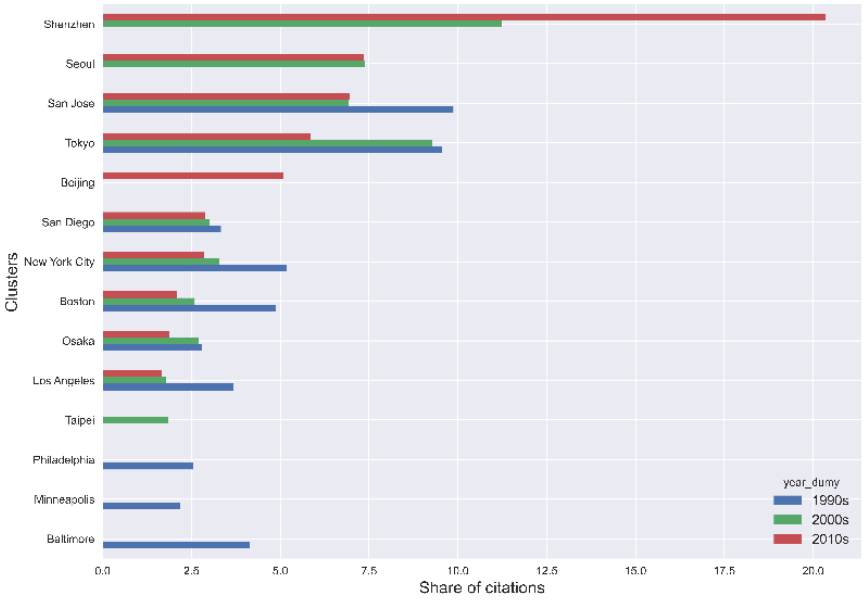
## *5.2 Shenzhen's knowledge sourcing*

Figure 14 depicts the top 10 clusters from which Shenzhen sources its technological knowledge. While the top three Eastern Asian innovation hotspots, that is, Seoul, Tokyo, and Osaka, as well as innovative hubs in the US, such as Silicon Valley, San Diego, New York and so on, continue to serves as Shenzhen's vital knowledge source, as observed above (WIPO, 2019), the contribution of international knowledge has

declined slightly. Shenzhen shows a significantly higher degree of reliance both on local (around 22 percent in the 2010s) and domestic knowledge. Through frequent interactions, Shenzhen has formed a mutually supporting relationship in knowledge supply and consumption with Beijing and Shanghai, although Shanghai relies more on Shenzhen than the other way around. In particular, the joint university campuses of many prestigious nonlocal research organizations play a key role in channeling external scientific knowledge to Shenzhen, further promoting Shenzhen's commercialization and the localization of external knowledge.

In addition, while being an important collaborative partner during the last two decades, Taipei no longer belongs among Shenzhen's top 10 knowledge sourcing clusters, indicating that knowledge sourcing areas change as a region climbs along the GIN.

***Figure 14: Top 10 knowledge sources of Shenzhen, Beijing, Shanghai, and Silicon Valley***




*Data source: WIPO-IES international patent family data*

# 6. Discussion

## *6.1 Conclusions*

Shenzhen's rapid development within 40 years from rice paddies to being among the top five Asian cities has been a miracle in economic history. A region with barely any capital, technology or skills, Shenzhen seized the historical opportunity of global industrial reallocation from capital-intensive to labor-intensive countries or regions and entered the GVC from low-end OEA activities and gradually moved up the value chain to OEM and then to high-end ODM and OBM in later stages. This industrialization process, achieved through climbing along the GVC, marks Shenzhen’s first and still ongoing leap. The second leap was Shenzhen’s transformation from imitator to indigenous innovator. With this transformation, Shenzhen became a technological leader in the GIN, rather than a mere follower. Thereafter, Shenzhen successfully upgraded from a labor-intensive, to a capital-intensive, then to a knowledge-intensive economy.

Based on the comparison of Shenzhen with other top Global Innovation Hotspots, such as Silicon Valley, Beijing and Shanghai, two major characteristics are identified from Shenzhen’s innovation ecosystem.

First, Shenzhen’s innovation ecosystem is dominated by domestic private enterprises. Contrary to Beijing and Shanghai, Shenzhen neither has strong state-owned enterprises nor rich local scientific research institutions. After its 40-year transformation and upgrading, Shenzhen formed a thriving and productive market-driven innovation ecosystem, where 90 percent of R&D investment and patent filings are from the private sector. The key transformation of Shenzhen’s innovation ecosystem saw domestic POEs replacing foreign companies to become the major driver of Shenzhen’s innovation upgrade.

Second, Shenzhen’s local innovation ecosystem is unbalanced in terms of scientific and technological knowledge base. Although Shenzhen’s technological output shares similar specialization patterns and trajectory to Silicon Valley, its early path was different from Silicon Valley’s model, which relies on technological transfer from universities. The initial conditions – a lack of local universities – led to Shenzhen’s innovation ecosystem lacking science-based innovation and local university–industry collaborations (UICs).

These two characteristics explain why Shenzhen’s technological trajectory followed a unique path in which its innovation arose directly from market demand. Shenzhen’s comparative advantage lies in the commercialization of existing knowledge and quick response to market demand by private enterprises. These private companies were

exposed to advanced management and technological knowledge of MNCs from developed countries and nearby HMT in the early stages. The rich scientific knowledge resources from Hong Kong and later Beijing provided necessary inputs to be commercialized. However, future development calls for more science-driven breakthrough innovation. This has become the bottleneck and major challenge for Shenzhen's future development.

### *6.2 Implications*

Shenzhen's transformation and upgrade process offers rich insights. First, it indicates that catching up and industrial upgrades have never been easy. It is a long-term process with ups and downs. For lag-behind regions with limited capital and technologies, entering the GVC from low value-added activities seems unavoidable. Second, Shenzhen's growth was initially tied to the GVC. Shenzhen achieved rapid industrialization through integration with and climbing along the GVC in the first two stages. The technological knowledge and capability accumulated prepared Shenzhen for its upgrading from a technological imitator to an indigenous innovator. Third, enhancing local innovation capacity through climbing up the GIN is key to further climbing along the GVC.

In particular, Shenzhen's second leap from an industrial cluster to an innovation hotspot is also a microcosm of China's transformation from "made in China" to "created in China." This successful upgrade from a technological follower to a global innovation leader has been achieved by 1) specialization in the ICT sector, 2) the forming of a vibrant domestic private-sector-centered innovation ecosystem, as well as 3) embeddedness into and close interactions with other regions in the GIN.

To be specific, Shenzhen's specialization in ICT and ICT-related technologies, as well as the strong industrial linkages within its local innovation ecosystem, led to it becoming a globally leading ICT innovation hotspot with the highest technological complexity in China.

Second, Shenzhen's evolution from copycat to indigenous innovator is inseparable from its domestic private-enterprises-dominated innovation ecosystem. The national-level policy encouraged indigenous innovation and local companies' efforts achieved technological independence and original innovation.

Last but not least, the fact that Shenzhen is in third place in creating highly original knowledge shows that weakness in the local scientific knowledge supply can be overcome by external linkages in the early stages, but indigenous innovation requires a region to develop local scientific capabilities.

### *6.3 Policy lessons*

Shenzhen offers rich policy lessons for developing countries and areas.

First, it shows that government and innovation policy both at the central and local level can play a pivotal role in regional catch-up and upgrading. Shenzhen's successful transformation into an innovation-driven economy is inseparable from the central government's support, as well as the regional government's continuous promotion of structural transformation and upgrading of the regional economic structure through the "*Vacating the Cage for New Birds*" policy. Meanwhile, the forward-looking innovation policies aimed at encouraging indigenous innovation through continuous reform and adjusting to changing industrial needs at each stage also facilitated Shenzhen's transformation. A set of policy tools, including building science parks and subsidizing entrepreneurship and SMEs' R&D activities, has encouraged local firms to invest in innovation and cultivate their technological capability for indigenous innovation.

Second, Shenzhen's case also displays the active role of government in the innovation ecosystem. Contrary to most Chinese cities, Shenzhen's government avoids intervening into the private sector's operation, and focuses on securing an international, market-oriented environment, building innovation infrastructure and encouraging internal and external collaborations, among other things. Specifically, the "*Build Nests to Attract Phoenixes*" policy, which means building infrastructure and facilities to attract investors and efficiently providing a range of excellent services, has been effective in encouraging exotic firms to relocate to Shenzhen and in incubating local start-ups. Within the last two decades, Shenzhen has heavily invested in building local infrastructure such as virtual university parks, Xili University Town, hosting a local campus of leading external scientific research institutes, Guangming Science City and many key national-level science labs. These measures have effectively overcome Shenzhen's shortage in local scientific knowledge supply and have substantially facilitated Shenzhen's catch-up. Additionally, the "*Peacock Plan*," which was launched in 2010, has attracted thousands of overseas and domestic talents migrating to Shenzhen through generous subsidies.

### *6.4 Future challenges*

Since 2018, Shenzhen has entered a new round of transformation. Accompanying its growing economy, soaring housing prices have pushed its R&D and living costs so high that many manufacturing companies – for instance, its largest taxpayer, Huawei's R&D division – have left Shenzhen. The fact that young people and small high-tech companies are fleeing from Shenzhen has caused nationwide concern about whether Shenzhen has also suffered from the so-called Silicon Valley Syndrome (Kwon and Sorenson, 2021) and has lost its competitiveness. Meanwhile, this troubled situation is further exacerbated by the US government's trade bans and technological sanctions

over China’s high-tech companies, the majority of which are based in Shenzhen. Such a worsening international environment exposes Shenzhen’s various weakness in many bottleneck technological fields, such as chip production, and imposes new challenges for its further integration into the GIN and its technological catch-up. In that sense, it is worthwhile to observe Shenzhen’s reaction, and whether it will be able to tackle these problems effectively and thus achieve a new round of upgrading.

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