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**Article**

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# Geography of knowledge interactions and innovation in Shenzhen

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## ABSTRACT

Recent studies have widely acknowledged that external knowledge sources derived from international collaborations play a pivotal role in driving innovation. Nevertheless, the Chinese government has taken a different approach by initiating an indigenous innovation policy, wherein the emphasis is placed on the synergistic effects of agglomeration and local knowledge bases as drivers of innovation. This study reinterprets the innovative dynamics in Shenzhen within the context of globalized and indigenous innovation policy. The research results show that Shenzhen's innovation dynamics have been shaped by local agglomeration but more importantly by international interactions. It is worth noting that international sources of products tend to generate higher profit margins. Based on the concept of knowledge bases, this study examines the micro-pattern of knowledge interactions in urban innovative dynamics and results show that the pattern is seen to be an interactional process between local and international knowledge flows, those interactions involve combining scientific knowledge or experience-based knowledge. The finding highlighted that urban innovation benefit from the knowledge interactions and the remarkable complementarity and interrelatedness at different spatial scales. Although there is limited interaction between local and international actors in the innovation process, local firms emphasize the importance of collaborative efforts towards innovation promotion. Thus, measures that ensure cohesive knowledge interaction networks support should be accelerated in the local innovative agents and international innovative agents to connect valuable knowledge sources, hence potentially breaking new paths of indigenous competitive advantage with external knowledge sources.

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## 1. Introduction

Over the last decade, with cities moving into the post-industrial period, the shift from an industrial to a knowledge-based economy has given rise to the urban innovation hub where cities leverage their respective knowledge, highly skilled workforce, capital, and potential resources to foster their growth and development (Dima et al., 2018).

Since the advent of cities in the post-industrial period, the dynamics of innovation have been extensively discussed in the academic world (Asheim et al., 2016; Malik et al., 2021; Pique et al., 2018). These studies intend to provide insights into the spatial heterogeneity of innovation (i.e. where innovative achievements concentrate and why some regions are more innovative than others), highlighting the relevance of the deep and wide interaction of local relations among innovation actors. Some scholars focus on the concept of 'agglomeration externalities', emphasizing the knowledge spillover and creativity afforded by dense region environments (Pan et al., 2020). However, there are also other studies questioning the extent to which agglomeration externalities and local interactions contribute to innovation (Cao et al., 2022; Chen et al., 2011), underscoring the importance of international collaboration. These studies suggest that the dynamics of innovation relied heavily on; innovation agents' learning and interactions locally or internationally. They examine the interplay between geographical location and interaction and place interaction within the context of geographical location. Nonetheless, the dynamic changes in local

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interactions and international connections in the institutional context have not been fully broached. First, urban innovation must consider and pay attention to the influence of trends and policy intervention. Those coordination skills may influence the performance of urban innovation. Peripheral regions in the past (or called Latecomer's advantage regions) are being exploited for policy capacity to advance their pursuit for technological advantages status, not only to catch up with international counterparts but to become innovation leaders. Second, in the knowledge economy undergoing innovation-driven, the confidentiality of innovation projects and closed innovative processes of foreign firms have made it difficult if not inadequate for absorbing external knowledge to play their roles in the making of innovation in emerging markets. The importance of innovation project commodification as a main source of profit for the project of innovation agents has turned innovation into a battlefield where various enterprises and institutions compete to take their anticipated benefits (see, for example, Ervits, 2018; Urbano et al., 2023). Many projects of innovation would meet strong competition from existing innovation agents until they are pleased with the profit to be generated from the projects. Therefore, the Chinese government has taken a different approach by initiating an indigenous innovation policy to enhance the knowledge base on their own. Third, such dynamic changes include knowledge resource quality, the learning capacity of innovation agents, and their interactions. Therefore, these regions require efficient policy to coordinate these constant dynamics.

Shenzhen serves as an intriguing case study due to its outstanding track record of innovation, placing it among the global leaders in this realm. While geographically adjacent to the international financial hub of Hong Kong, Shenzhen is primarily known for its prowess in the hardware industry. In recent years, the local government has prioritized indigenous innovation and the development of domestic firms (Li et al., 2020; Liu et al. 2023). This emphasis on fostering innovation from within has necessitated an expansion of existing theoretical frameworks to comprehend how interaction within cities influences innovation.

The dynamics of innovation in cities have long been a subject of debate among academics that refers to the theoretical and territorial landscape previously elaborated. Conceptually, the influences of good agglomeration effect, international connections, and policy intervention have been proven to affect urban innovation (Caragliu & Del Bo, 2019; Niebuhr et al., 2020; Wang et al., 2023). As the cities across the world found their ways to stimulate innovative through accumulative specialized labor, attract foreign investment, and strengthen education system, new theoretical issues are raised concerning how indigenous innovation capacity have been improved in different cities to reshape spatial inequality of the innovation. Recent studies have argued that the extant literature laid too much emphasis on human capital accumulation and agglomeration effect in the dynamics of innovation but ignored the influence of knowledge interactions that are the key to unpacking urban innovation (Lin et al., 2021). Therefore, the present study will stand as an essential benchmark by filling the gap by proposing knowledge interactive pattern to solve Shenzhen's innovative dynamics problem. The research investigated the extent of urban innovative dynamics influence and the ways of knowledge interactions under this catch-up policy background, especially (i) what are the patterns of knowledge interaction that drive processes of innovation in Shenzhen, (ii) how do these interactions differ between local and international innovative actors, and (iii) how innovative actors combine knowledge provided by different sources.

This study identifies several contributions. First, this study identifies the micro-pattern of knowledge interactions in urban innovative dynamics, that is external knowledge combinations are seen to be the logic explaining the success of the innovation, and interaction seen to be most favourable when the partners (local or international) involved have some related variety of knowledge. Second, different from the existing studies that focus on agglomeration effects from human capital in the same city, this study distinguishes knowledge interactions of innovation actors in the same city, that is their interactions involve combining scientific knowledge or experience-based knowledge which enriches the research on the dynamics of urban innovation. Third, this study integrates innovative dynamics in Shenzhen as the research object, providing important empirical evidence for China to adopt innovation catch-up policies, and provide experience for other developing countries to learn from Shenzhen's experience to enhance the vitality of urban technological innovation.

This article is structured as follows: Sections 1 and 2 present the competing interpretations of innovation dynamism in cities and introduce an analytical framework. The methodology and data are

presented in Section 3, while Section 4 focuses on the local practices of industrial innovation identified from Shenzhen to further explore the factors affecting Shenzhen's innovative achievement. This article concludes with a summary of the findings for theoretical and policy implications.

## 2. Interpreting the dynamics of innovation in cities

### 2.1. *The impact of agglomeration and proximity*

Urban regions are witnessing a growing number of innovative activities. Consequently, innovation has garnered significant attention as key factor for sustained competitive advantage and economic growth (Ahmad et al., 2021; Belderbos et al., 2014; Fan et al., 2021; Zhang & Wu, 2019). Economic geographers have been actively investigating the spatial heterogeneity of innovation, seeking to identify where innovative achievements concentrate and why certain regions exhibit greater innovation than others. The concentration of innovation in specific regions can be attributed to a range of locally specific factors. Human capital endowments and agglomeration are identified as the major factors. Recently, the argument stresses to attribute the innovation of cities to the agglomeration effect is built on conditions that there exists similar or related innovative actors tend to assemble, professional labor market, specialized technical services suppliers, and that information exchange is effectively accessed (Fan et al., 2021; Li & Zhang, 2020). Nevertheless, these conditions can hardly be found in many developing countries where professional labor are not accumulated, cultivation of talents is subject to education systems immaturity, and information flow are limited (Florida et al., 2017; Pan et al., 2020). These market and infrastructural conditions would impose severe constraints upon the agglomeration effect. Subsequent urban innovation research efforts have sought to expand the agglomeration effect by highlighting the discourse of knowledge spillover (Hou, 2022; Kekezi et al., 2022; Wang et al., 2023), for example, a close relationship develops among related innovation actors operating within a given urban area, allowing them to convene and exchange insights on topics of shared interest. Such discussions facilitate the flow of knowledge and foster various forms of ideas, learning, and innovation. When innovation actors interact with one another, either through collaboration or competition, within the same industry, it tends to create an open atmosphere that promotes learning and innovation. Under such circumstances, an innovation actor has increased opportunities to engage with individuals who possess well-developed technology, enabling the transfer of tacit knowledge, such as ideas and experiences, from one actor to another.

The concept of 'proximity' has been introduced to give due emphasis on knowledge creation and innovation. The main argument is that proximity is recognized as a mechanism facilitating interactive learning, new knowledge creation, and innovation processes (Boschma, 2005). Various forms of proximity encourage innovative agents to engage in innovation. Existing studies discuss various forms of proximity, including geographical proximity (Santamaría et al., 2021), cognitive proximity (Houessou et al., 2023; Stojčić, 2021), social proximity (Johnston, 2022), and organizational proximity (Alpaydın & Fitjar, 2020; Liu et al., 2021). These studies show that suitable geographical distance, related knowledge base, good institutions, and policy support promote innovation. As social proximity and cultural proximity factors and innovation become more relevant, there will be more interaction and trust between innovative actors with closer social-cultural customs (e.g. language or religion), thereby enhancing innovative cooperation (Davies et al., 2021; Tang et al., 2020; Walsh et al., 2022). However, the excessive proximity of social-cultural customs may produce poor inclusivity and the diversified innovation is limited. Existing studies on the proximity effect are mainly based on the national level, especially the proximity effect between the East and West countries; however, different countries vary in their perspectives, such as politics and culture. Such interference factors cannot be ruled out when studying different nations. In this study, the dynamics of innovation within a city are examined, which eliminates other disturbances.

However, several studies have questioned the positive benefits brought by agglomeration and cognitive proximity. Critics argue that excessive local cognitive proximity can lead to a reliance on established thinking and ideas, (Fitjar & Rodríguez-Pose, 2020; Malik et al., 2021), a phenomenon known as 'cognitive lock-in' (Visser & Boschma, 2004). With the advancement of infrastructure and communication

technology, innovation cooperation can break through territorial boundaries and expand outward. From an economic geography perspective, moving away from the spatial proximity view of innovation to a relational view, greater attention has been paid to knowledge interactions, and latest studies emphasize the importance of external sources of knowledge and international interaction. The subsequent section will delve into these arguments in greater detail.

## **2.2. Knowledge interactions and innovation**

In the context of globalization, innovation processes have become increasingly complex. The binary argument of whether knowledge is derived from internal or external sources is no longer sufficient to understand knowledge creation, learning, and innovation. The concept of knowledge bases provides some further insights into how firms innovate, and how innovation actors source knowledge (Asheim & Coenen, 2005; Medase & Abdul-Basit, 2020). Knowledge bases refer to co-existing tacit and codified forms of knowledge but in different combinations. In this context, a knowledge base includes 'analytical' and 'synthetic' types of knowledge base. An analytical knowledge base pertains to economic activities that involve scientific knowledge and research-oriented segments. Codified knowledge inputs and outputs are common, and outcomes are often documented in scientific papers, reports, software files, or patent descriptions. These activities require specific capabilities such as analytical skills, theory-building, and testing, as well as the ability to work with codified knowledge effectively (Trippel & Tödtling, 2007). On the other hand, a synthetic knowledge base refers to economic activities where innovation primarily occurs through the application or novel combination of existing knowledge, such as business-oriented services and customized production. These activities are often influenced by workplace experience, learning by doing, and interactive processes (Martin & Moodysson, 2013). Therefore, economic activities characterized by a synthetic knowledge base heavily rely on tacit knowledge.

Some recent studies examine the impact of combinatorial knowledge on firms' innovation output. For example, Alhusen and Bennat (2020) examines innovation modes in SMEs and highlights that cognitive, organizational and financial barriers are the biggest obstacles impeding innovation outputs. Acharya et al. (2022) focus on the impact of knowledge integration and enterprise innovation from a common meaning perspective, and find that common interests strengthen to collate and process knowledge, thereby improving innovation.

As mentioned earlier, research on the relationship between innovation agglomeration and between corporate innovation and knowledge bases is extensive. However, research on the link between urban innovation, agglomeration and knowledge bases remains limited. Scholars focus on knowledge integration at the firm level and neglect knowledge integration within cities. Existing research on the promotion of urban innovation by knowledge bases in cities is still lacking at the micro level. Thus, based on the concept of knowledge bases, this study examines the impact mechanism of local and international interactions on innovative actors in the city at the micro level.

## **2.3. Geography of knowledge integrations**

The literature of knowledge bases have offered valuable insights with the relevance of knowledge interactions and innovation processes, more specifically, geography of knowledge interactions (Asheim, 2019; Miguelez & Moreno, 2018; Yurevich et al., 2023). To avoid cognitive lock-in, urban innovation processes also rely on international knowledge sources. More specifically, while the local knowledge structure within each innovation actor may be similar, these actors actively seek ideas from external sources within their region. Take innovation actors in cities, for instance, who actively search for and engage with advanced technology owners to access fresh external knowledge. This process involves various mechanisms of interactive learning and observation. Through learning and observing, these innovation actors assimilate and recombine ideas, thereby stimulating the generation of innovation. A case study conducted by Sugiharti et al. (2022) in Indonesia suggests that even countries in remote regions can benefit from promoting certain international interaction. Similarly, a case study examining the ICT industries in India goes a step further, suggesting that both networks transcending cities and national international

networks are crucial dynamics driving local innovation (Malik et al., 2021). The innovation process is understood as an interactional process between local and international knowledge flows, and these interactions may become a remarkable complementarity element that creates interrelatedness. In several developing cities where the human capital and the conditions of infrastructure are poor, placing the emphasis on the role of agglomeration effect at the expense of knowledge interactions may well obscure the factors of urban innovation.

Shenzhen is one of the most rapidly urbanized cities in the world. Over the past four decades, Shenzhen has transformed from a low-cost manufacturing hub to a high-tech industrial activity center. While technology transfer and dependence on foreign technology played a crucial role in its development, they were not sustainable strategies for fostering innovation. In 2006, the Chinese government launched a national science and technology program focused on 'indigenous innovation'. This program aimed to enhance Shenzhen's capacity for innovation by assimilating foreign technology and promoting domestic innovation (Fu et al., 2011; Li et al., 2020). In line with this national policy, the Shenzhen government placed significant emphasis on the development of high-tech industries and R&D in an attempt to boost economic growth by increasing the city's capacity for innovation. Political intervention and openness mean its innovation faces more knowledge interactions challenges than other cities. In this context, what is the current situation of innovation in this city?

To understanding why and how certain cities exhibit greater innovation than others lies in the interaction of local and international knowledge flows holding complementary values and associated in the process of innovation. Those cities capable of forging cohesive knowledge interaction networks are likely to be successful in enhancing their innovation capacity. Hence, understanding the dynamics of innovation requires an examination of context-specific practices and experiences in different cities. This paper tests the socioeconomic factors between local and international expenditure in influencing innovation, and focuses on analysing the urban innovative dynamics under the influence of knowledge interactions differences to clarify the impact of complex knowledge interactions on urban innovation and make up for the existing literatures.

### 3. Methods and study area

Linear regression analysis was used to test the influence of local interactions and international interactions on technological innovation of Shenzhen. Meanwhile, the qualitative approach is adopted in this study to examine the patterns of innovation dynamics within different city policy contexts. The dynamics of innovation in cities have been widely studied, including how these dynamics drive innovation and how different actors interact within the innovation process.

Shenzhen is intentionally selected as a case study for research on city innovation due to its implementation of the 'indigenous innovation' policy, which provides valuable insights into the various paths of urban innovative dynamics. The city is currently undergoing significant economic, demographic, and innovation developments, making it an ideal subject for the study. One of the key reasons Shenzhen was chosen is its status as a hub for information and communication technology (ICT) and a center for high-tech industrial activities (Zacharias & Tang, 2010). It has fostered the growth of numerous innovative companies, including Huawei Technologies Co., Ltd, which was founded in Shenzhen in 1987. The city is commonly referred to as the "Silicon Valley of China" due to its remarkable achievements in the high-tech sector. This aligns perfectly with the industrial structure of Shenzhen, which is well-suited for the ICT industry. Moreover, it is worth noting that the largest research and development (R&D) expenditures are concentrated in a few sectors globally, with ICT being one of them (United Nations Conference on Trade and Development, 2020). Consequently, studying the ICT R&D sector in Shenzhen offers valuable insights into urban innovative dynamics.

We consider that the dynamics of innovation may change within the context of China's indigenous innovation policy. Thus, it is valuable to explore the insights gained from Shenzhen's experiences in order to understand the paths of urban innovation. These experiences can serve as important references for researching urban innovation in other cities. The hypothesis proposed in this study is that the dynamics of innovation in Shenzhen depend on two types of corporately coordinated forces – local agglomeration and international interactions.

### **3.1. Variable measurement**

In this particular study, the definition of innovation is limited to newly developed products, as defined by Gallouj and Weinstein (1997). The dynamics of innovation are analyzed by considering the scope of cooperation and interaction present within Shenzhen's innovation process. The scope of cooperation encompasses both local and international partners, while the available modes of interaction include collaborative research and development, technology transfer, and shared equipment. Interaction available may take the modes of collaborative R&D, transfer of technology, or shared equipment. In addition, it also includes the interaction between innovation actors and the urban environment. This study focuses on some elements of innovation, such as highly skilled professionals, universities, and research institutions (Belderbos et al., 2014; Du et al., 2022), providing a valuable lens through which to understand the dynamics and achievements of innovation and assess the impact of interaction levels.

Several indicators need to be quantified. Following existing literature (Rodríguez-Pose et al., 2021; Wu et al., 2019) on the measurement of urban innovation, the following variable is constructed: The dependent variable is the urban innovative capacity (UIC), which is determined by calculating the share of new products in the city's GDP. To capture the level of local interaction, we measure the percentage of local R&D expenditure out of the total expenditure (RDE). This indicator helps to gauge the extent to which local innovation actors in the city are engaging in interactions, such as staff salaries, project expenditure, or contract amounts, to stimulate innovation. Additionally, we measure international interaction by analyzing the percentage of foreign R&D expenditure out of the total FDI expenditure (FRD). Economic growth is also considered by examining the level of GDP, and the urban scale is evaluated using population density (POD) as a proxy.

### **3.2. Sample selection and data sources**

The empirical analysis focuses on city statistics in Shenzhen from 2009 to 2021. All city-level panel data, including R&D expenditure of innovative agents locally and internationally, population size, and GDP were gathered from the Shenzhen City Statistical Yearbooks.

The interview data for this study were collected from interviews, while secondary data from academic journals and government reports. The qualitative research approach employed purposive sampling to identify innovation actors or informants who could provide authentic information relevant to Shenzhen. The goal was to ensure a comprehensive representation of all stakeholders involved in innovation, including government officials, professionals from universities/research institutes, representatives from enterprises, and members of industry associations. By selecting informants from these different groups, the study aimed to capture diverse perspectives and experiences that could shed light on the actions taken to promote innovation in the city. The researchers posed questions to understand the various ways in which these innovation actors have cooperated and the effectiveness of their actions in achieving desired outcomes. The objective was to uncover the extent of interactions and knowledge exchanges among these actors and assess how they have impacted innovation. Fieldwork for this study was conducted in Shenzhen from September to November 2021. A total of 12 in-depth interviews and two telephone interviews were conducted with the selected informants. The interviews varied in duration, ranging from thirty minutes to two hours. To complement the interview data, this study also reviewed the interactions documented in innovation reports and analyzed the balance between local agglomeration and international interactions that influence innovation in Shenzhen.

## **4. The dynamics of innovation in Shenzhen**

### **4.1. Empirical analysis**

The linear regression analysis was used to test the influence of local interactions and international interactions on urban innovation capacity in Shenzhen. It is crucial to address any multicollinearity issues in the dataset before presenting the findings. Table 1 shows the parameters used for the Durbin-Watson

**Table 1.** Model summary.

Model	R	R squared	Adjusted R squared	Std. error of the estimate	Durbin-Watson
1	.948 <sup>a</sup>	.898	.848	.02335	2.044

**Table 2.** Descriptives.

Variable	Mean	SD
UIC (The Share of New Products in GDP)	.4809	.05981
RDE (Intensity of R&D Expenditure)	.0468	.01510
FRD (Foreign R&D Expenditure/FDI (10000 Yuan))	.0714	.10932
GDP (GDP in Shenzhen)	19162.8702	7223.75787
POD (population density)	5955.2308	1082.05439

**Table 3.** The regression results.

Model		Unstandardized coefficients		Standardized coefficients		Collinearity statistics		
		B	Std. Error	Beta	t	Sig	Tolerance	VIF
1	(Constant)	.291	.045		6.429	.000		
	FRD	.360	.078	.659	4.615	.002	.624	1.604
	RDE	-1.204	.476	-.304	-2.532	.035	.881	1.134
	GDP	7.568E-06	.000	.914	3.814	.005	.221	4.522
	POD	1.259E-05	.000	.228	1.053	.323	.271	3.685

Note: Significant: \* $p < .05$ , \*\* $p < .01$ .

test. A value close to 2 indicates minimal or no evidence of significant autocorrelation. This implies that the errors or residual errors are independent, validating the use of regression results for analysis. Moreover, the R-squared value is employed to gauge the explanatory power of the independent variables in elucidating the dependent variable. An R-squared greater than 0.75 denotes a high explanatory capacity (Hair et al., 2010). Therefore, the four variables together significantly explain 89.8% of the variance observed in the dependent variable. Table 2 reports the descriptive statistics of the variables included in the empirical analysis.

Predictors: (Constant): POD (population density), RDE (Intensity of R&D Expenditure), FRD (Foreign R&D Expenditure/FDI (100 million Yuan)), GDP (GDP in Shenzhen/100 million Yuan)

Dependent variable: UIC (The Share of New Products in GDP).

Table 3 displays the collinearity statistics of VIF, with a VIF < 10 indicating the absence of multicollinearity in each variable (Hair et al., 2010). The Durbin-Watson parameter and VIF suggest that the regression results are valid for analysis. The findings reveal a positive and statistically significant association between GDP and urban innovative capacity (UIC), indicating that higher levels of economic growth attract innovation actors to engage in innovation activities. In cities with stronger economic foundations, more financial capital may be concentrated towards innovation endeavors, possibly due to the continuous input of capital required for complex knowledge and the development of competitive new products. The significant positive relationship between foreign R&D expenditure/FDI (FRD) and the proportion of new products in GDP (UIC) suggests that international connections contribute to the enhancement of innovation dynamics in Shenzhen. By interacting with foreign enterprises, Shenzhen's performance in innovation is improved, allowing innovation actors in the city to benefit from the exchange of knowledge and experiences with international counterparts. This finding aligns with existing theories highlighting the dependence of urban innovation dynamics on international knowledge sources (Trippel et al., 2018). Therefore, both economically developed cities (e.g. Shenzhen) and remote regional countries (e.g. Norway) stand to gain from fostering international interactions to boost their innovation capabilities.

There is a negative statistically significant relationship between local R&D expenditure (RDE) and the share of new products in GDP (UIC), and this can be attributed to two primary factors. First, a considerable portion of R&D projects are considered high-risk ventures, often requiring substantial investment and numerous experiments before yielding any returns or achieving lower returns. This is particularly true when innovation actors venture into uncharted technological territories. Second, not all R&D investments can be translated into profitable new products or financial gains. Innovation actors often allocate

resources to research projects that focus on basic or theoretical research, which are inherently time-consuming and do not directly generate profits. The findings of this study align with recent research discoveries that highlight the varying impact of R&D expenditure on innovation performance. Some studies indicate that R&D investments tend to favor larger companies or market leaders (Voutsinas et al., 2018), while others suggest a negative and statistically significant relationship between R&D expenditure and profitability (Curtis et al., 2020). The nature of R&D projects, such as incremental innovation (Acemoglu et al., 2022), coupled with their inherent riskiness, can contribute to lower profit returns.

Furthermore, it is worth noting that population density (POD) does not necessarily play a significant role in promoting urban innovation. The findings mentioned above indicate that simply having a higher population density does not guarantee a higher level of innovation. Instead, this study highlights the importance of interactions and knowledge sharing in fostering innovative environments.

#### 4.2. Local and international interactions on innovative actors in the city at the micro level

Over the past decade, China has witnessed a noteworthy transformation in its growth dynamics, shifting its focus from industrialization towards embracing technological innovation. This shift has brought about significant changes in China's economic landscape, with Shenzhen emerging as a leading city at the forefront of this innovation-led growth. The increasingly competitive environment in all regions of China has prompted the authorities in Shenzhen to recognize the value of innovation. They have become more proactive in fostering the growth of high-tech industries and promoting innovation as a key driver of urban development. This strategic focus on innovation has propelled Shenzhen into a new era of economic growth.

A closer look at the data reveals the tangible impact of this innovation-driven approach. Figure 1 indicates a steady growth in the share of new product profits in Shenzhen's GDP since 2009. In fact, by 2021, the share of new product profits in the city's GDP had reached an impressive 55.9%. This statistic further exemplifies the pivotal role that innovation plays in driving Shenzhen's economic expansion.

The analysis of descriptive statistics reveals a consistent and significant increase in the density of R&D employees from 2009 to 2021. This growth is depicted in Figure 2, which provides a visual representation of the density of R&D employees in urban areas.

Does agglomeration occupy a position of greater importance in those cities with a professional labor force? A director from the Research Institute detailed the agglomeration:

'Our institute is currently exploring a fascinating concept known as the 'upstairs-downstairs innovation complex,' where the laboratory is situated upstairs and the enterprise operates downstairs. The primary objective of this model is to significantly reduce the time it takes to translate ideas into actual products. Technology companies, in particular, often find themselves spending excessive amounts of time in this process, and if they fail to navigate through it efficiently, they may find themselves in what is commonly referred to as the 'valley of death' – a situation that incurs greater costs and delays. Under this innovative model, companies and research institutes collaborate on the use of equipment, enabling start-ups to initiate their research and

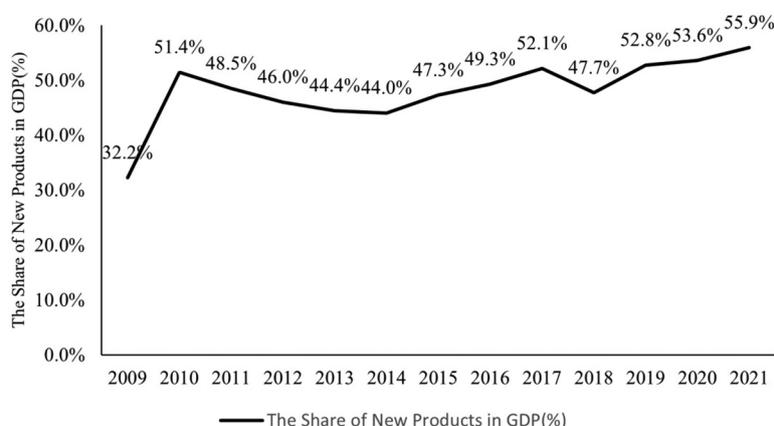
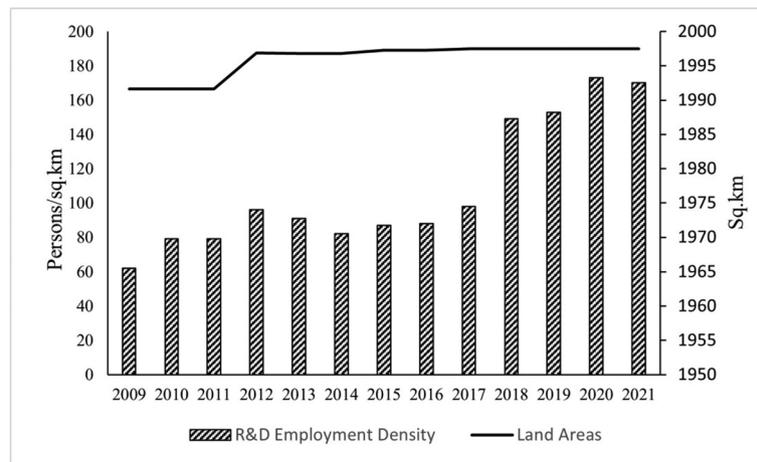


Figure 1. The share of new products in GDP.



**Figure 2.** R&D employees' density in Shenzhen, 2009–2021.

development endeavors at a minimal cost. Simultaneously, the institute offers intellectual support to these companies, creating a mutually beneficial environment. Picture lab-coated researchers and suit-clad corporate employees coexisting within the same building, sharing the same elevator. A simple technical problem that arises during the course of work could potentially find a solution right then and there.' (Interview conducted on November 10th, 2021)

Geographical proximity plays a significant role in facilitating knowledge exchange and fostering innovation among various actors. This is particularly evident in the case of innovation within the mobile phone industry. A developer from another communication company mentioned that:

'Our company operates in the mobile phone industry and we are actively seeking collaborations with related enterprises. We maintain frequent exchanges with our partners, such as the recent collaboration with BYD in the production of our latest mobile phone model, the ZTE Axon 30. BYD, a prominent enterprise, has a factory conveniently located in the Longgang District of Shenzhen, which is just a short half-hour drive away from our company. This proximity enables seamless communication and eliminates the need for extensive travel, resulting in cost-effective and efficient collaborations. In the dynamic field of mobile phone manufacturing and research and development, effective communication is essential. The design of mobile phone components must carefully consider production feasibility, making face-to-face interactions vital.' (Interviewed on 12/10/2021)"

For experience-based knowledge, the informant shows that Shenzhen companies rely more strongly on information and ideas they get from their suppliers/partners. Contacts with other firms (in the same industry or value chain) are the most important sources of experience-based knowledge. In Shenzhen, the city level is most important for experience-based knowledge links with university suppliers for local companies. Thus, geographic proximity is more relevant for knowledge links based on experience-based knowledge. Innovation actors face unique challenges when striving for innovation in dense urban environments. To shed light on this phenomenon, a university professor provides insights into the interactions involved in the innovation process.

'Our university team has conducted extensive research on Thin-Film Transistor (TFT), which is an advanced display technology. Through our efforts, we have successfully developed a new TFT integrated circuit technology that has been adopted for mass production in a leading company's bezel display. As a result, we have entered into a mutually beneficial partnership where we receive a percentage of the profits generated from the sales of these displays. Although we did not collaborate directly with the enterprise during the development phase, we transferred the patent for our invention to a prominent flat panel display company'. (Interviewed on 14/09/2021)

The prevailing trend among companies is to seek out creative and complex technologies that necessitate external knowledge, ideas, and support. Universities and research institutions are often the hubs of groundbreaking ideas and unique technologies, making them crucial sources of new knowledge. Linkages to universities and research institutions play an important role for local firms when it comes to gathering

technological knowledge, their activities show a high inclination towards radical innovation as reflected by university teams claiming to develop products that are new to the market. By collaborating with companies, universities, and other public research institutions, companies can combine their own resources, such as capital, with the complementary resources of their partners, including proven technology. This effective integration allows companies to tap into a wider pool of expertise and enhance their innovation capabilities.

Shenzhen's unique geographical condition has facilitated the exchange of ideas and fostered a culture of learning. The local interaction among innovation actors in the city is a clear indication of the progress made in terms of innovation. These findings align with established theories, which suggest that agglomeration alone does not guarantee interaction. Rather, it is the ability of agglomeration to facilitate interactions that is relevant to the dynamics of innovation. More specifically, innovation actors actively engage in intentional actions and purposeful behavior to establish interactions within their geographical proximity. This stimulating environment encourages the exchange of diverse ideas and promotes continuous learning in various ways (Malmberg & Maskell, 2002). Additionally, the presence of affiliated institutions and research centers from prestigious Chinese universities such as Peking University and Tsinghua University further supports R&D collaboration and knowledge dissemination. Compared to other innovation hubs like Silicon Valley and London, Shenzhen boasts a multitude of competitive research universities and institutes that contribute to the technological advancements of companies in the region (Engel et al., 2018; Pique et al., 2018). This robust network of intensive interaction and connections between idea exchanges and learning plays a significant role in explaining the dynamics of innovation in Shenzhen.

#### 4.3. The balance between local agglomeration and international interaction that affects innovation

In order to further examine the impact of the balance between local agglomeration and international interaction on innovation, a descriptive statistical analysis conducted in 2021 has provided some interesting findings. The analysis reveals that the input-output ratio of new products of foreign-funded enterprises is 2.63/1805.88 (100 million RMB). On the other hand, the input-output ratio of local enterprises is 1679.52/15340.67 (100 million RMB), which means that for every 1% of new product R & D expenditure, the new product income for foreign enterprises is 75 times that of local enterprises (Shenzhen Municipality Bureau Statistics, 2021). These results suggest that international investment plays a far more significant role in generating revenue from new products compared to localized expenditure.

Further investigation into the open access report on the Renewed project (Table 4) demonstrates that foreign companies have limited engagement with local companies and that they tend to focus on

**Table 4.** Interactions among innovation actors of R&D activities in Shenzhen ICT industry.

Type	Cooperation actors	Purpose of interactions
Local	Peking University Shenzhen Graduate School	Collaborative R&D
	Huawei Technologies Co., Ltd	Transfer of technology
	Skyworth Group Co., Ltd	Access to equipment
	Small and medium-sized Enterprises (SMEs)	
	Shenzhen Communication and Information Processing Laboratory	Collaborative R&D
	University of Hong Kong	Technical assistance
	French National Academy of Applied Sciences (France)	
	Research Institute of Tsinghua University in Shenzhen	Collaborative R&D
	Zhongxing Telecom Equipment	Joint training of students
	Huawei Technologies Co., Ltd	
International	The Chinese University of Hong Kong (Shenzhen)	
	Apple Inc. (Shenzhen) R&D Centers, US	Human resources Access to markets Transfer of technology
	Accenture, Ireland	Access to IP
	Oracle Information Technology Services (Shenzhen) Co. US	Human resources Access to markets
	Qualcomm, US	Collaborative R&D
	Silu Mingyang Communication Technology Co., Ltd. Shenzhen	
	Shenzhen University	

Source: Adapted from Shenzhen Municipal Service Data Administration.2021.

accessing human resources and markets, as indicated by the presence of international companies in [Table 4](#). The spatial pattern of knowledge sources for foreign companies shows that the local innovative actors have less contact to other foreign knowledge providers. This preference can be attributed to their status as market leaders and their inclination towards internal R&D efforts. However, it is worth noting that local innovation actors have the potential to learn from and adapt the products of these market leaders. For instance, the appearance design and camera features of the iPhone have served as inspiration for local mobile device actors, leading them to learn from and redesign their own products (ChinaDaily, 2015). This demonstrates the importance of international knowledge sources in urban innovation. Meanwhile, local innovation actors actively engage in observation and learning as intentional actions to foster innovation.

Shenzhen's innovative dynamics are found to be shaped not only by forces of local agglomeration but more importantly by international interactions. These two forces seem to be understood as the way innovation actors intentionally learn and knowledge interact in the innovation process. The dynamics of innovation in Silicon Valley show a similar trajectory to that of Shenzhen. Local innovation actors need to cooperate with other actors, such as research universities and companies. However, there are some notable differences between the two. In Silicon Valley, market leaders with greater technological advantages have been fostered, leading to closer interactions that support innovative growth. Many regions, including Shenzhen, look to Silicon Valley as a source of inspiration for achieving competitive catch-up. Shenzhen's early economic growth was fueled by foreign direct investment (FDI), as its economy relied on fulfilling production orders for foreign companies. However, with the introduction of the indigenous innovation policy, Shenzhen needs to leverage its technical advantage to achieve a competitive catch-up. However, as revealed by this research, there is still much work to be done in order to realize this vision. Policymakers and stakeholders must actively promote local and international interactions, with a particular emphasis on collective and interdisciplinary learning among innovation actors.

## 5. Discussion

By conducting a multiple linear regression analysis, the study finds that Shenzhen's innovation dynamics are shaped not only by local agglomeration but also by international interactions. Interestingly, the analysis reveals a negative and statistically significant relationship between the local intensity of R&D expenditure and the share of new products in the city's GDP. This suggests that not all investments in R&D lead to profitable new products or increased profits. Instead, innovation activities in Shenzhen tend to focus on research projects that are more focused on basic or theoretical research. While these projects are time-consuming and may not directly translate into profits, they provide a strong foundation for future innovation. The multiple linear regression analysis reveals a positive and statistically significant relationship between foreign R&D expenditure and the share of new products in Shenzhen's GDP. This suggests that international actors have exerted significant influence on the city's innovation.

Further insights are gained through interviews conducted with innovative individuals who were asked about the 'return on agglomeration'. From a micro perspective, agglomeration provides a convenient geographical condition for the exchange of experience-based knowledge in business-oriented environment. In Shenzhen, the city level is most important for experience-based knowledge links with university suppliers for local companies. Thus, geographic proximity is more relevant for knowledge links based on experience-based knowledge. In an effort to achieve self-sufficient technological development, the Chinese government has implemented a policy of 'independent innovation', urging domestic innovators such as enterprises, universities, and research institutions to lead advanced technology development. However, Shenzhen's experience in implementing this policy appears to be less successful than anticipated.

The case of Shenzhen lies in how innovation actors interacted with diverse local forces. Local innovation actors achieve the transfer of technology or collaborative R&D by taking advantage of their finance and knowledge. Innovation actors from Shenzhen (i.e. universities, research institutions, and firms) often have analytical knowledge or synthetic knowledge interactions with each other, while intentional knowledge combinations can become significant in the innovation process. Linkages to universities and research institutions play an important role for local firms when it comes to gathering technological knowledge, more specifically, developing products in which innovation takes place mainly through novel

combinations of scientific knowledge and capabilities such as analytical skills, abstraction, theory-building and testing. For experience-based knowledge, contacts along to other firms (in the same industry or value chain) are the most important sources for experience-based knowledge, this process in which innovation takes place mainly through a novel combination of experience gained at the workplace and through production by doing. From a theoretical perspective, this study verifies the importance of agglomeration, interactions, and knowledge combinations in Shenzhen city's innovation. The findings from interviews indicate the importance of innovation by an intentional or active diversified knowledge combination taken with external innovation actors in dense urban environments. The results demonstrate that MNCs usually rarely work with local firms in Shenzhen but intentionally access to the domestic market. They are usually tough competitors because they are international market leaders (e.g. Apple Inc, Qualcomm, etc.). Therefore, such rare interaction in Shenzhen indicates the efforts of stakeholders to establish cooperative relationships with international market leaders.

The study's findings are consistent with those of macro-level studies that consider cities as the whole research object, such as Hervás-Oliver et al., (2021) and Ali (2021). Urban innovation benefits greatly from international sources. The input of use-value knowledge and expenditure has significantly intensified innovation efforts. However, when it comes to risky or technically complex innovative projects, the return on expenditure often falls short. As a result, creative and complex technologies have emerged as key drivers of competitive advantage (Azeem et al., 2021). To effectively develop and leverage such complex technologies, diverse methods have been employed, one of which is known as 'open innovation' (Chesbrough & Appleyard, 2007). However, Shenzhen, despite being a hub of innovation, lacks meaningful interactions between local and international actors. Consequently, local innovators tend to earn fewer profits from new products compared to their international counterparts. In the case of urban innovation, redistribution of R&D expenditure and the process of knowledge combination play a crucial role, in this respect, external knowledge combinations are seen to be the logic explaining the success of the innovation, and interaction seen to be most favourable when the partners (local, or international) involved have some related variety of knowledge.

## 6. Conclusion

In recent years, there has been much debate surrounding the development of innovation in the post-industrial era and the emergence of the global knowledge economy. Some key questions have emerged, including how innovation is fostered, why certain regions outperform others in terms of innovation, and what factors drive urban innovation. The existing body of literature has emphasized the importance of international interactions and dynamics that transcend urban boundaries in driving urban innovation.

Currently, research on the link between urban innovation and knowledge bases remains limited. It remains unclear whether some cities have successfully implemented catch-up policies to capitalize on their innovation advantage. In order to shed light on these issues, this study examines the micro-pattern of knowledge interactions in urban innovative dynamics. First, this study tests the influence of R&D expenditure differences between the local and international in Shenzhen, on urban innovation, and the results show that local innovation agents and international innovation agents have a significant impact on urban innovation. Innovative agents in international region innovate more than innovative agents in local region. It is worth noting that international sources of products tend to generate higher profit margins. Second, based on the concept of knowledge bases, this study examines the micro-pattern of knowledge interactions in urban innovative dynamics and results show that the pattern is seen to be an interactional process between local and international knowledge flows, those interactions involve combining scientific knowledge or experience-based knowledge. Their partners being located inside the city or outside the country. Importantly, geographic proximity is more relevant for innovative activities based on experience-based knowledge, while innovative agents with their interaction coming from international less than innovative agents from the local, local firms emphasize the importance of collaborative efforts towards innovation promotion.

The study's findings suggest that the urban environment is compact in its layout, and innovative agents are frequent in communication, innovation benefits from when the partners (local, or international) involved have some complementary and interrelated knowledge. Measures to support urban

innovation efforts should primarily consider design to the architecture spatial, and target innovation activities that are at the core of each specific industry. Furthermore, measures that ensure cohesive knowledge interaction networks support should be accelerated in the local innovative agents and international innovative agents to connect valuable knowledge resources, hence potentially breaking new paths of indigenous competitive advantage with external knowledge sources.

Shenzhen is a city that diligently adheres to its 'indigenous innovation policy', but it also recognizes the significance of local–international interactions in driving urban innovation. Only when these two forces work collaboratively and are properly balanced, can the city fully maximize its innovative capacity. Giving due consideration to the synergy between local and international actors in Shenzhen is crucial for fostering urban innovation.

This case study serves as a starting point, shedding light on the practical application of the changes of innovative dynamics where have adopted catch-up innovation strategies in a city. Future research should consider a deeper understanding of the role of institutions in the dynamics of urban innovation in the knowledge economy, it is necessary to conduct further research comparing Shenzhen's approach to urban innovation with that of other cities. By examining how different 'latecomer's advantage cities' implement catch-up on innovative advantage, we can unravel the complexities and learn valuable insights that contribute to enhancing urban innovation on a broader scale.

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No potential conflict of interest was reported by the author(s).

### Author contributions

Sharifah Rohayah Sheikh Dawood was involved in the conception and design and revising it critically for intellectual content. Jiaxiong Huang was involved in the drafting of the paper, and the acquisition analysis and interpretation of the data, and the final approval of the version to be published. Jiaxiong Huang agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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### Data availability statement

Data will be available on request. Authors agree to make data and materials supporting the results or analyses presented in their paper available upon reasonable request. The data that support the findings of this study are available in [SHENZHEN STATISTICAL YEARBOOK] at [<http://tjj.sz.gov.cn/zwgk/zfxxgkml/tjsj/tjnj/>]. The data of interviews that support the findings of this study are available from the author, [J.X], upon reasonable request.

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