Chin. Geogra. Sci. 2022 Vol. 32 No. 2 pp. 237−250
https://doi.org/10.1007/s11769-022-1267-3

Springer Science Press
www.springerlink.com/content/1002-0063

Urban Chemical Industrial Cluster Area Restructuring and Determinants: A Case Study of a Typical Old Chemical Industry Area Along the Yangtze River, China

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Abstract: China is in a transitional period between urban renewal and industrial change. In this period, the focus has been on the suburbanization of enterprises and land transformation in old industrial areas, particularly areas with chemical industries. A life cycle theoretical framework was established to develop chemical industrial zones in the context of urban expansion and land function conversion. The long-term historical processes and mechanisms that transformed a typical old chemical industry area along the Yangtze River, Yanziji Area of Nanjing City were unveiled and comparatively analyzed. The study found that the entire life cycle of the case study area was formed through the combined action of different influencing factors. Traditional industrial location factors played important roles during the rise and continuity of the chemical industry zone, while unconventional environmental regulations and government policies drove its decline and transformation. In the transformation of the old chemical zone, the renewal and redevelopment of industrial land into higher-value residential land is a key link determining the feasibility of government fund compensation and the circulation of capital. These findings demonstrate that regional control and environmental regulation play crucial roles in determining the location of polluting industries and the renewal of urban industrial areas. This research enhances the understanding of the development history and reconstruction of chemical industry clusters and plots within megacities at a finer geographic scale.

Keywords: industrial land; chemical industry zone; urban renewal; industrial suburbanization; old chemical industry area

Citation: ZOU Hui, DUAN Xuejun, JIN Tingting, 2022. Urban Chemical Industrial Cluster Area Restructuring and Determinants: A Case Study of a Typical Old Chemical Industry Area Along the Yangtze River, China. *Chinese Geographical Science*, 32(2): 237−250. https://doi.org/10.1007/s11769-022-1267-3

1 Introduction

In the process of globalization, changes in manufacturing structure and location are gaining momentum in many developed and developing countries (Zhu, 2000; Niu et al., 2020; Yang et al., 2020). This has also led to changes in land use for urban manufacturing clusters and surrounding areas. The expansion of urban areas in developing countries has meant that the mixed use of residential and industrial land has become relatively common (Leaf, 2002). For a typical urban area in China, industrial land accounts for 30%–50% of the total non-agricultural land, with clear interference from space and industrial land (Tian et al., 2017). Among the various land use types, the supply of industrial land has played an important role in promoting the growth of the manu-

Received date: 2021-01-04; accepted date: 2021-05-06
Foundation item: Under the auspices of the National Natural Science Foundation of China (No. 41901156, 42071164); Project of the Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences (No. NIGLAS2019QD011)
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facturing industry and local development (Zhou et al., 2019). Although the mixed use of residential, commercial, and recreational land is desirable to attain a compact city model, the mixed use of residential and industrial land has long been considered harmful to the living environment (Tian et al., 2017). This equates to disturbances in the lives of urban residents and has an increased detrimental impact on the ecological environment.

It is inevitable that economic development will trigger urban expansion, changes in industrial structure and environmental impact, industrial transfer, and the transformation of old industrial bases. The dynamic interaction between the local government and the market has greatly affected the urban development model, and the transformation of industrial land is no exception (Zhang et al., 2018). The tendency for manufacturing industries to migrate from dense central cities to spacious urban fringe areas is referred to as 'manufacturing suburbs' and may be traced back to trends in developed countries in the mid-19th century, particularly in North American metropolitan areas (Nicolaides, 2006). Although researchers have acquired a better understanding on the general phenomenon of industrial suburbanization (White, 1976), this research is still in its infancy as regards developing countries (Shen and Wu, 2013; Zhang et al., 2018; Wu et al., 2020). Europe and the United States have rich experiences in the renovation and renewal of old industrial areas. However, in developed countries and regions, the transformation of old industrial areas is mainly carried out for economic development to a certain stage and industrial growth, whereas in China, such transformation is based more on considerations for ecological environment protection, health risk avoidance, and urban land appreciation. As an economic practice, the relocation of enterprises and the transformation of industrial areas take place in different economic and institutional environments (Hudson, 2002; Kapitsinis, 2018). In the past, there has been considerable attention on the migration process of enterprises from old industrial areas to the suburbs. However, the historical process and mechanisms underpinning the growth and transformation of old industrial areas have been ignored.

Existing studies have focused on the evolution and driving of industrial spaces before and after the suburbanization of the manufacturing industry (White, 1976; Wu et al., 2020). They tend to study how the government uses intervention policies to attract enterprises to relocate to the suburbs (Zheng and Shi, 2018), but often ignore how the government can force enterprises to relocate through improved environmental regulations and special policies. Existing research on industrial land and the transformation of old industrial areas mostly focuses on land use policies and land prices (Chen et al., 2018); however, research on the origin of industrial land and its entire life cycle process is scarce. At the same time, in terms of the government's role, the research is keen to analyze the government's 'race to the bottom' behavior, while ignoring the government's 'race to the top' behavior. In some of China's large cities where the economy has developed to a higher level, local governments are not merely pursuing economic growth and maintaining enterprises, but actively optimizing the industrial structure and layout to improve the environment and residents' health and welfare. In these cities, the role of the government is unclear and the lack of cases is a challenge. Therefore, it is necessary to conduct a comprehensive investigation and research on a long-term scale on typical cases to reveal the historical driving forces behind the transformation process of old industrial areas.

The development of the polluting manufacturing industry as represented by the chemical industry, has entered a stage of accelerated transformation and upgrades. This process has played an important role in the economic growth of most cities in China over the past 40 yr (Chen et al., 2018; Jiahuey et al., 2019). The chemical industry is the most representative manufacturing industry; it is an important pillar promoting economic growth, while also being a major source of urban pollution and environmental damage (Zhang et al., 2009). The chemical industry concentration area is an industrial agglomeration area characterized by significant negative externalities (López-Navarro et al., 2018). Therefore, the selection and transformation of land of areas with a high concentration of chemical industries is an important component, directly reflective of regional/urban planning decisions. When urban expansion encircles the former chemical zone on the city fringes, industrial and urban-living lands are intertwined, greatly promoting the 'suburbanization' and relocation of the old chemical zone. This phenomenon is very common in China's big cities. Understanding this

phenomenon and its underlying mechanism is conducive to understanding the development of Chinese cities in transition. This article supplements existing literature on industrial location and urban land-renewal research.

Based on corporate data, historical documents, field surveys, and interviews, this research provides a new perspective for investigating the historical development and transformation of old industrial areas. Drawing on industrial location theory, urban land expansion and renewal theory, environmental externalities, and political economy, this paper constructs a theoretical analysis framework and studies cases of a typical old chemical industry area along the Yangtze River in Nanjing City, China. The outcomes from this research may aid the understanding on the trajectory and logic of 'New Economic Geography' and 'Urban Renewal' in the context of China and other developing countries or transition economies.

2 Conceptual Framework

Many theoretical and empirical studies have explored various determinants of factory site selection, location changes, and industrial land conversion. Broadly, the choice of location of an enterprise is impacted by three factors, namely regional attributes, government intervention, and enterprise attributes (Zheng and Shi, 2018). In classical and neoclassical economic models, areas with the lowest production costs and the highest profit are the best locations for manufacturing companies (Hayter, 1997). The new economic geographic model further emphasizes the impact of agglomeration economies on the structural adjustment of manufacturing. Due to the effects of new institutional economics, increasing attention has been focused on the role of government intervention in industrial development.

Natural advantages often explain the location of many industries and their concentration in specific geographic spaces (López-Navarro et al., 2018). The layout along the river has become a natural advantage for many companies, particularly during the early stages of industrial layout. Transportation costs, financial capital, land, and labor are considered the main location factors (Thompson and Miller, 1978). The accessibility of transportation and infrastructure has an important impact on urban development and corporate location selection (He et al., 2008; Zhao and Hu, 2019; Wang et al., 2020). In particular, when transportation costs are sufficiently low, companies that produce differentiated products tend to gather in large cities. This geographic concentration may generate positive externalities, attracting a greater number of new businesses (Zheng and Shi, 2018), and ultimately offering economic benefits to the economic development of the region.

However, the high concentration of industries, particularly polluting industries, increases social and environmental costs, leading to greater negative externalities (Kyriakopoulou and Xepapadeas, 2013). The impact of industrial environmental pollution on the health of citizens has been widely documented in the literature (López-Navarro et al., 2018). Further, these industrial gatherings also lead to an increase in land prices. Since the land commercialization in 1988, the price and quantity of land supply in China have become core factors affecting the layout of the manufacturing industry (He et al., 2007). High land rent in the city center inhibits industry, while low land rent in the periphery of the city tends to attract industry (Zhang et al., 2018). Land prices and pollution costs, which are important components in the production costs of chemical companies, will play a central role. External environmental and social costs may be incurred during industrial transfer, accompanied by a series of economic and social issues, also impacting industrial transfer. Furthermore, based on new economic geography and institutional economics, many factors will affect industrial transfer, including agglomeration economy, transportation infrastructure, human capital characteristics, taxation, and environmental regulation. Changes in land use efficiency and structure as a result of industrial transfer are of great significance and a theoretical reference for urban renewal and development (Chen et al., 2018; Mao et al., 2020).

This previous research has contributed to the theory of industrial suburbanization, industrial agglomeration area transformation, and land renewal in the context of urban transformation. The findings from this research have guiding significance in terms of understanding the formation mechanisms and transformation and renewal of chemical industry zones. A theoretical analysis framework was developed by combining the findings from previous literature (Fig. 1). We constructed the concept of the 'life cycle' evolution of the entire chemical zone and chemical land.

The product life cycle theory explains the entire pro-

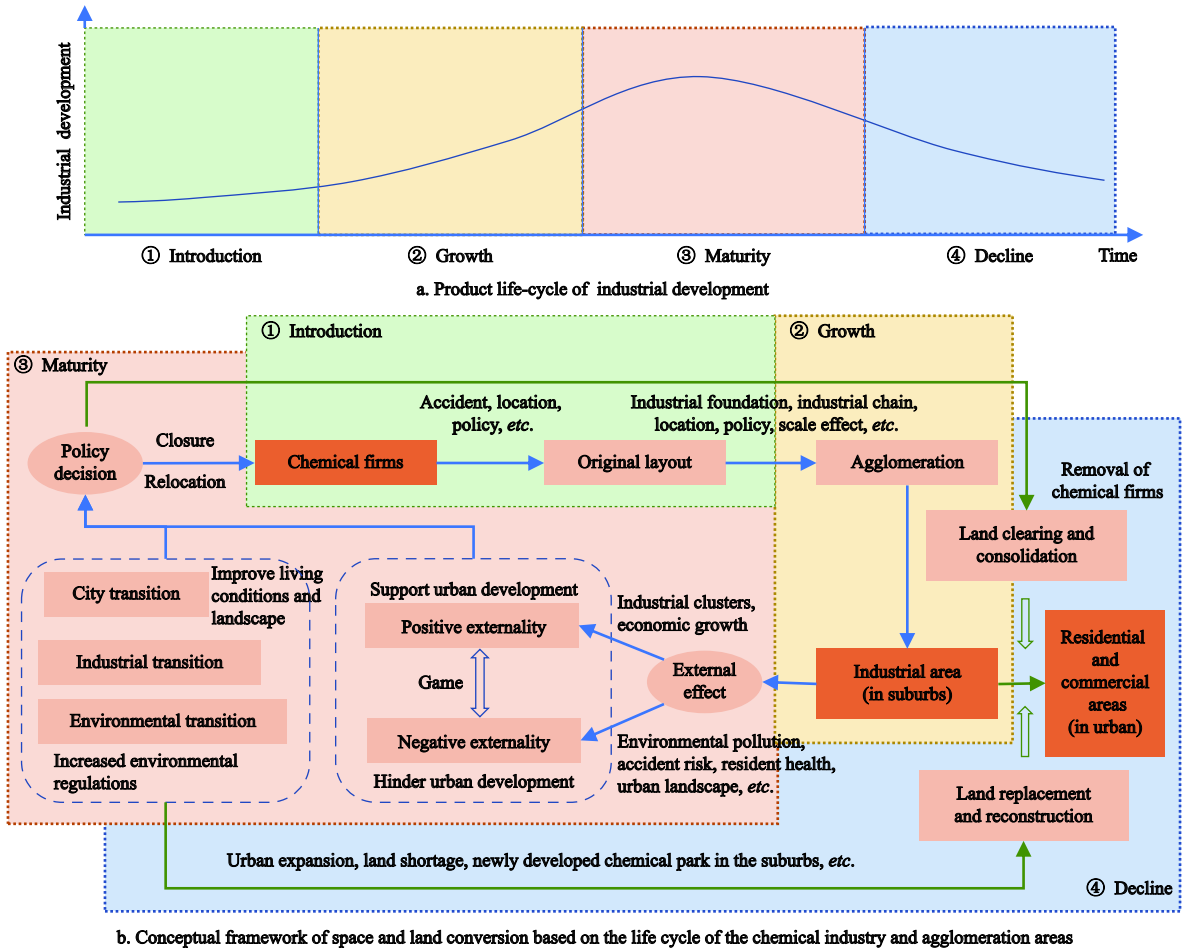


Fig. 1 Conceptual framework of product life-cycle of industrial development (a) and space and land conversion based on the life cycle of the chemical industry and agglomeration areas (b)

cess of a new product from entering the market to being eliminated by the market (Asl-Najafi and Yaghoubi, 2021). It is generally divided into four stages, namely introduction, growth, maturity, and decline periods. The chemical industry agglomeration area and its affiliated products conform to the phase characteristics of the product life cycle theory, from the distribution of a few enterprises to the development of large-scale agglomeration, and then to relocation and exit.

(1) Introductory period: the original layout of chemical companies is shaped by accidental factors, location factors, and policy factors. The layout during this period is often in line with the industrial location theory. Especially, riverside location is the most preferred choice for chemical companies because of convenient shipping and water source availability. At this stage, chemical companies consider safety and are often far away from the main urban and residential areas of the city.

(2) Growth period: relying on the existing industrial foundation and industrial chain, the early chemical zone is more likely to attract upstream and downstream industrial clusters. From a few enterprises to large-scale industrial clusters, the development of chemical parks gradually gains advantages in scale. However, as a whole, at this stage, the industrial park is still located in the suburbs; it does not have excessive negative impact on the development of the city, so as to maintain its own development advantages.

(3) Maturity period: after a period of rapid growth, the infrastructure, supporting industrial facilities, and policy services of the chemical concentration area are fully developed. Externalities gradually become prominent, including both positive and negative externalities. Positive externalities are manifested in the cost advantages brought by industrial agglomeration to promote industrial development and support the city's economy, while negative externalities are manifested in environmental pollution, damage to residents' health, life safety

risks, and poor urban landscape caused by agglomeration. The status of positive and negative externalities is communicated to the city's decision makers. Simultaneously, the strengthening of various environmental regulations also begins to increase the cost of production and squeeze the growth space of the industry.

4) Decline period: with the strengthening of negative externalities, production costs gradually increase. With the acceleration of urban development, the main urban and residential areas continue to expand, resulting in the expansion of land use contradictions. At the same time, with the gradual shortage of land in the main urban areas, the price of industrial land gradually becomes less advantageous, and the price of land gradually exerts centrifugal force, and the trend of industrial suburbanization is prominent. Then, with the combined action of the government, market, enterprises, and the public, the relocation and closure of chemical companies are promoted, and the industrial zone gradually declines. Finally, the land is reorganized and redeveloped, and the original suburban professional chemical park is transformed into commercial and residential land in the main urban area.

The theoretical framework integrates product life cycle theory and industrial location theory, urban land expansion and renewal theory, environmental externality, political economy, and other theories. The development of the chemical zone is divided into four stages, describing the complete life cycle of the chemical zone from formation, development, and prosperity to decline and extinction. Second, the theory introduces the concept of positive and negative externalities, and proposes the game and contradictions from the perspective of agglomeration to promote economic growth, hinder the development of the main urban area, and influence policy making and government decision-making. In particular, negative externalities are not obvious in general industrial companies, but are most prominent in chemical companies with high pollution and high risks. Third, the impact of changes in the scope of the main urban area of the city is proposed. That is, in the early stage of development, the chemical park is located in the suburbs, and in the middle and late stages it is surrounded by cities. This change in urban spatial form is often the most direct cause of the suburbanization of polluting manufacturing industries because the location of city suburbs has changed. Finally, the theory puts forward the hypothesis of land conversion, that is, the conversion of industrial land in the chemical zone to residential and commercial land. This is based on the derivation of urban land conversion based on the land rent theory and political economy theory. This is because only the generation of greater comprehensive value (mainly economic value) after the renewal of the land can effectively make up for the capital vacancy caused by the relocation and closure of a large number of enterprises. This is also an effective way to explain the conversion of the land value and the return of funds in the process of urban industrial land renewal in developing countries.

3 Data and Method

3.1 The case study area

The case study area, the Yanziji Area, is located in the northeast of the main urban area of Nanjing (Fig. 2). It is an old chemical concentration area in Nanjing, known as its chemical cradle (Xu and Shao, 2014), and is considered to present a very good Chinese case study for this research. The uniqueness of the evolution process of the Nanjing Yanziji Chemical Concentration Zone is manifested in three aspects. First, this chemical zone has a long history and is one of the birthplaces and important gathering places for the modern inorganic chemical industry in China. Its evolution and transformation process have complete and long-time clues. Second, this chemical zone has a large number of foreign-funded enterprises, which can better reflect the changes in China's industrial policy and the drive of globalization policies, and link localization and globalization together. Third, this region has a unique geographical location in a typical urban-rural transition zone and along the Yangtze River. It not only reflects the transformation process of China's urbanization and industrialization, but also reflects China's strategic transformation from the development of the Yangtze River to its protection.

3.2 Data sources and research interviews

The enterprise data in this study were sourced from the China Industrial Enterprises Database (http://microdata.sozdata.com/). Historical data were sourced from historical documents, such as the Nanjing City Planning Annals (Xi, 2008) and Nanjing Chemical Plant Annals (Editor's Office of Nanjing Chemical Plant Records, 1997). Remote sensing data were obtained from Google histor-

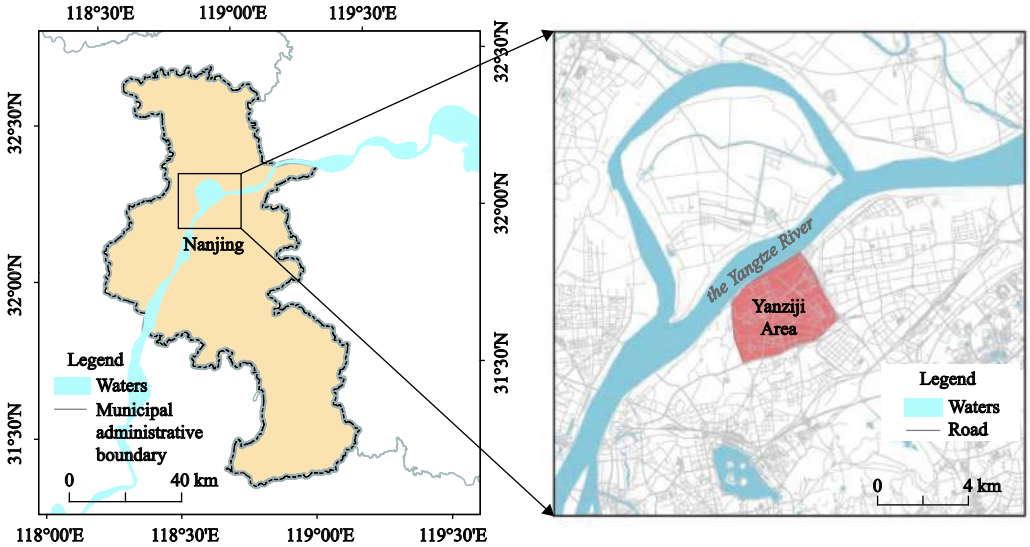


Fig. 2 Location of the Yanziji Area along the Yangtze River

ical imagery (http://www.bigemap.com/). In 2016, we conducted interviews and field investigations in the case study of the Yanziji Area. Interviewees included government officials, researchers from scientific research institutions, and residents of the chemical industry zone (Table 1, Fig. 3). Through field research and interviews, we selected and listed the interview records of 4 interviewees, whose represented government departments, provincial and municipal research institutions, and the public. Interviews were face-to-face and generally 30–60 min long. The interviewee's views combined with quantitative data analysis can effectively support

Table 1 Profiles of interviewees interviewed on the development of Yanziji Chemical Industry Zone

Interviewee	Title, Organization	Date	Contents
Interviewee#1	Official, Nanjing Chemical Industrial Park Ecological Environment Bureau	Sep., 2016	Nanjing Chemical Industry Development Policy
Interviewee#2	Professor, Nanjing Institute of Environmental Science	Nov., 2016	Transformation Process of Chemical Industry in Yanziji Area
Interviewee#3	Professor, Jiangsu Institute of Environmental Science	Nov., 2016	Jiangsu Chemical Industry Development Policy
Interviewee#4	Resident, Yanziji Area, Nanjing	Oct., 2016	Changes before and after relocation of chemical companies

Fig. 3 Field investigation of the Yanziji Area along the Yangtze River

the arguments and verify the theoretical framework.

4 Results

4.1 The origin, agglomeration, and externality of the old chemical zone

The chemical industry in the Yanziji Area originated from the Nanjing Factory of the original Central Chemical Plant Preparatory Office established in 1936. At that time, site selection was mainly based on the advantages of access to the water resources from the Yangtze River, the water transportation conditions, and accidental factors. The plant was renamed as Nanjing Chemical Plant in 1949. In the 1950s and 1970s, a small number of state-owned chemical plants, relying on the industrial foundation and national policies, were gradually deployed in the region. Following economic reforms in China and its openness to the outside world in 1978, private enterprises in this area developed rapidly, and many upstream and downstream enterprises gathered with the Nanjing Chemical Plant as the core. In the 1990s, globalization also introduced capital investments from Germany and other foreign countries to the region. Chemical companies continued to gather, and chemical industry clusters continued to grow. Around 2000, a large number of chemical enterprises were newly built, and the industry developed rapidly (Fig. 4). This area gradually became a well-known chemical base in Nanjing and more so throughout China, with more than 100 chemical companies during its most prolific period. These were the first (the introduction stage) and second (the growth stage) stages mentioned in the theoretical framework. After the wave of reform and opening up and globalization, the park has continued to grow and develop. However, in the third stage (mature stage), negative externalities began to appear.

The continuous agglomeration of industries contributed significantly to the regional economy, while also generating huge negative externalities. First, these industries have impacted and damaged the regional environment. Due to their location upwind of Nanjing, industrial pollution emissions and odors have a significant impact on the city. Additionally, wastewater discharge from chemical plants pollutes the Yangtze River.

The Yanziji Area of Nanjing has two main problems. First, chemical companies are relatively concentrated, all of which are small chemical companies, that cause serious odor pollution. Second, companies do not rule out sneak shots (Interviewee#1, 2016).

Second, residential and industrial land in this area was arranged alternately owing to the continuous expansion of the city. This introduced huge safety risks, whereby accidents caused by chemical companies were frequent occurrences. The impact and risks of the chemical industry on local residents have also been the focus of the literature (Dakkoune et al., 2018; Chen and Reniers, 2020).

There are many old residential areas in Yanziji, and these residential areas are adjacent to the industrial area. There have previously been explosions, and the underground oil pipe exploded. From safety to the environment, and to the image of the city, urban residents are dissatisfied as shown by their increasing complaints and environmental disputes (Interviewee#2, 2016).

In the past, we could smell the pungent smell of rotten eggs even with the windows closed. Sometimes an explosion occurs, and the glass of the window is shaking (Interviewee#4, 2016).

4.2 Chemical industry zone transformation and land conversion

In response to the increasing negative externalities, the

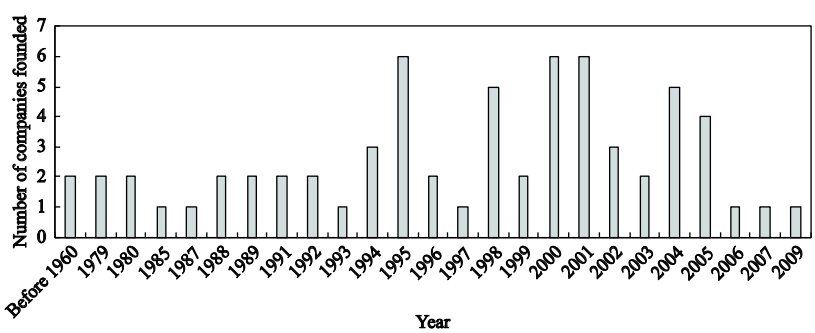


Fig. 4 Number of chemical enterprises established in the Yanziji Area

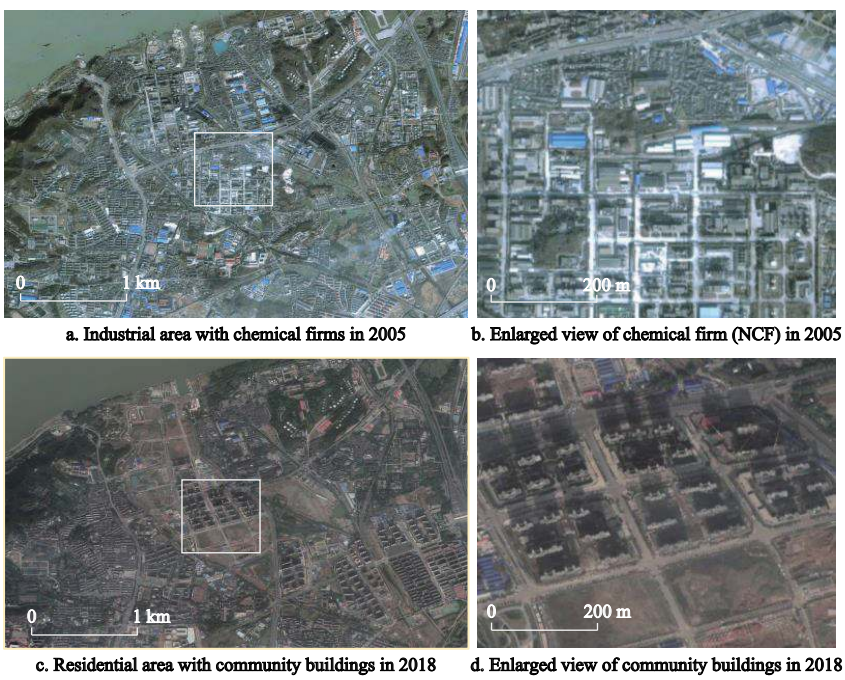
Yanziji Area underwent a transformation process. In 2006, Jiangsu Province and Nanjing City successively issued notices on special rectification plans for chemical production enterprises. These policies prohibited the development of new chemical companies in the Yanziji Area and concurrently formulated relocation plans for existing companies. Since the end of 2007, the overall relocation of Sinopec's Nanjing Chemical Plant and the Nanjing Chemical Fiber Plant signified the prelude to the relocation, demolition, and renovation of chemical companies in the Yanziji Area. In 2010, the Nanjing Municipal Government issued a special policy, the 'Announcement on Comprehensive Remediation of Chemical Production Enterprises in Yanziji Area', prompting chemical companies in the area to suspend production and accelerate remediation actions. From 2011 to 2012, 66 chemical companies in the region were shut down and transferred. The main direction of suburbanization occurred in the Nanjing Chemical Industry Park, north of the city.

Some of the enterprises moved out from Yanziji, some went to Nanjing Chemical Park, some went to Yancheng and Lianyungang, and some went to Anhui Province. There were also some enterprise owners who were getting old and their children were unwilling to take over. They have received government compensation (some companies have received tens of millions) and stopped conducting their business (Interviewee#1, 2016).

In the fourth stage (the recession stage), the enterprises in the chemical park entered recession and relocation, and new business formats appeared. The regional environmental quality improved significantly following the relocation of chemical companies. Yanziji New City will be transformed from an old industrial base into a comprehensive service-oriented new urban area with an ecological and livable riverside. The demolition of old concentrated residential areas and the establishment of new residential communities reflect the conversion of chemical land to residential land (Fig. 5).

In the past, no one wanted to live here (in the Yanziji Area). Housing prices were very low. Now, housing prices are rising slowly. Many people from other parts of Nanjing and outsiders buy houses here (Interviewee#4, 2016).

During relocation and reconstruction, the case study area mainly relied on administrative power to close or move companies through compulsory orders and government subsidies. During the relocation process, large chemical companies in the Nanjing Yanziji Area moved into Nanjing Chemical Park, while some relatively small companies moved to northern Jiangsu and Anhui (Fig. 6). Merchants migrated to regions that could increase profitability through the use of spatially different socioeconomic frameworks (Kapitsinis, 2018). The un-



a. Industrial area with chemical firms in 2005 b. Enlarged view of chemical firm (NCF) in 2005

c. Residential area with community buildings in 2018 d. Enlarged view of community buildings in 2018

Fig. 5 Conversion of industrial land into residential land in the Yanziji Area

dertaking grounds outside Nanjing were all within 300 km. Prefectures and cities in Anhui Province were also cities close to Nanjing, showing obvious geographic proximity (Shen et al., 2019). The relocation process of chemical enterprises depicted the characteristics of a separate layout of corporate headquarters and production bases (Boyang et al., 2014; Gao et al., 2017). For example, the Nanjing Ningkang Chemical Production Base was moved to Huaian Hongze Salt Chemical Park, although its headquarters are still in Nanjing. In terms of the utilization of the transformed land, the land was reused for real estate development only because this was the way in which the government investment in the transformation of relocated enterprises could be recovered. This was also in line with the optimal results of the multi-party dynamics between government, enterprises, and residents. It is also a classic model and case of old chemical transformation and urban renewal (Hu et al., 2019; Zhang et al., 2019; Zhou et al., 2019).

4.3 Historical stage division and driving mechanism

The driving factors vary across different periods and can be divided into three stages. During the first stage (before 1980), the development of the chemical industry was mainly due to the industrial foundation of the Nanjing chemical plant and the advantages of Nanjing City. During the second stage, in the 1980s and the 1990s, upstream and downstream production companies began to gather to rapidly develop the economy. The main rivers included industrial foundation, geographical advantage of the proximity to the Yangtze River (e.g., abundant waterfront resources and convenient transportation of raw materials) and foreign investment. During the third stage, since the 21st century, the region has experienced major environmental problems, with frequent safety accidents and hard feedback from residents. The expansion of the main urban area in the city caused the chemical clusters originally located in the suburbs to intersect with the main urban area. In conjunction with this, the central government had also been focusing greater attention on the ecological and environmental protection of the Yangtze riverside area, whereby there have been increasing efforts to remediate the negative impacts of the chemical industry at the provincial level. This prompted the Nanjing municipal government to issue special measures to relocate and remediate the chemical companies in the area. This action reflects the changes in the driving force of the agglomeration-proliferation (closure) of chemical companies and the conversion of industrial zones in the region at different stages (Fig. 7).

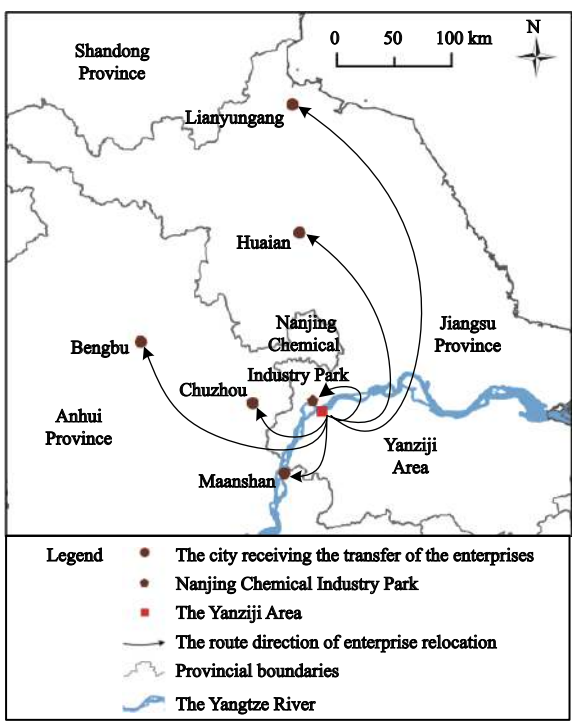


Fig. 6 Main relocation paths of chemical companies in the Yanziji Area

In the above three stages, government forces played an important role, but there are also differences and characteristics in different stages. In the first stage, the government mainly played the main management role of the planned economy and vigorously developed state-owned chemical enterprises. With China's reform and opening up and economic system reform, the government played a role in attracting corporate investment in the second and early stages of the third stage. In the latter part of the third phase, the government began to change its role, and no longer welcomed these industries that polluted the environment and were unpopular with the public, and began to issue various policies to drive them away. Among these stages, the government has the strongest power in the first and third phases, while the second phase is precisely where the market plays a greater role and promotes industrial agglomeration and development.

The government has played a key role, mainly by compensating enterprises for the relocation to facilitate

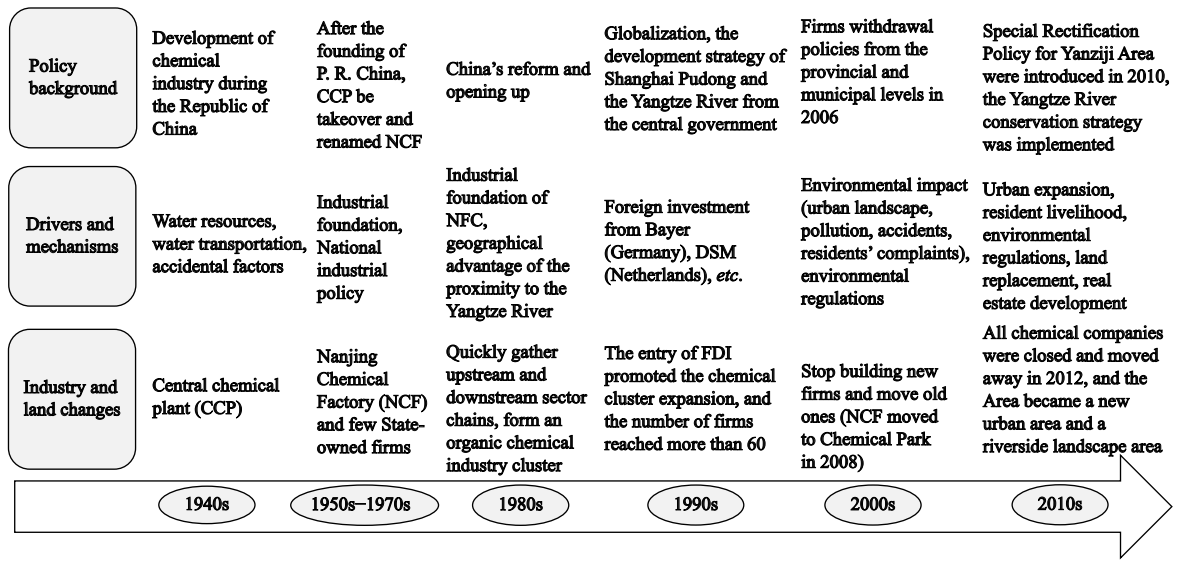


Fig. 7 Historical transformation process of land and enterprises in the Nanjing Yanziji Area

land reclamation for redevelopment.

The transformation of the Yanziji Area is closely related to urban development. The transformation of Yanziji hopes to move the enterprises away, replace the land, and create profits. If the companies move to the north of the Yangtze River (Nanjing Chemical Park), the cost of relocation must be subsidized for the companies. The land there may be free of charge, while the land here is handed over. After the land is taken back, it is leveled, repaired, and re-flowed into the market. Perhaps money is made back during this process (Interviewee#2, 2016).

The driving force underpinning the relocation of chemical companies in the Yanziji Area of Nanjing mainly includes government policies (such as environmental regulations and industrial policies), the public image of the company, and development.

The company's image must also be improved. Originally, the corporate image mixed in that place was scattered, dilapidated, and small in scale. Companies that have moved from Yanziji to the Chemical Industry Park are considered to be decent, standardized construction companies (Interviewee#1, 2016).

The government gave full consideration to environmental factors when making decisions in addition to many other factors, including urban development, urban image, land replacement, and the livelihood of residents. This also confirms the theoretical hypothesis that government decision-making is driven by the game of positive and negative externalities, environmental regulations, urban development, and people's livelihoods, and at the same time, it is also affected by the policies of the central government.

The environment plays 50% of the role in the relocation of chemical companies in the Yanziji Area, while the other half is comprehensive consideration from government, which is worthwhile. The relocation of Yanziji has merit from the perspective of environmental planning and urban construction (Interviewee#2, 2016).

Jiangsu Province (including Nanjing City) adopts a green development level assessment to assess the construction of ecological civilizations, which has stimulated the enthusiasm of local governments to protect the environment. However, we should not only consider environmental protection; we also need to balance environmental protection and economic development (Interviewee#3, 2016).

5 Discussion

5.1 Historical stage and influence mechanisms

This study reveals the combined effect of the land parcel and the entire 'life cycle' of the chemical industry it carries, and its different influencing factors (Fig. 7). The theoretical framework may be confirmed based on the increased contradictions of externalities at a certain stage that are confronted by the development of industrial parks; this means that the contradictions between positive and negative external effects have increased. The positive external effects of the development of in-

dustrial zones include the economic growth experienced by the city, tax revenue for the government, and the provision of employment. Negative external effects include industrial pollution emissions, environmental and safety risks, threats to the health of residents, and complaints and dissatisfaction of residents due to the industrial zone being surrounded by the main urban area. In fact, these dynamics have always existed, playing various roles in different periods and stages, consistent with existing research findings on manufacturing (Gao et al., 2018).

Since the mid-1990s, China's fiscal decentralization has transformed the government's role in local economic development, having a significant impact on land allocation and revenue (Liu et al., 2016). Local governments accepted their new role in land supply and transfer, with the dual goal of increasing revenue and attracting investment (Yuan et al., 2019). In particular, since 2006, the central government in China carried out a series of land market reforms, having a significant impact on the site selection decisions of companies and the government's attitude toward industrial land (Zheng and Shi, 2018; Xie et al., 2018; Zhou et al., 2019). This land policy also directly or indirectly affects the development and transformation of the old chemical zone. The reform policies of the Nanjing Yanziji Area had commenced in 2006 (Fig. 7), and it may be deemed that they have been largely affected by national-level land reform and the global financial crisis of 2007. Studies have shown that corporate relocation is a dynamic affected by broader potential forces, such as globalization (Kapitsinis, 2018); this is also inseparable from land-use efficiency and policies. Related research shows that denser enterprise clusters and preferential policies cannot further improve the land-use efficiency of enterprises in industrial zones (Sun et al., 2020). Therefore, when the old chemical zone develops to a certain stage, internal land use efficiency also becomes an important negative external factor. This also confirms that the negative externalities proposed in the theoretical framework come into play in the third period (maturity period) (Fig. 1).

With the strengthening of environmental protection regulations, the traditional manufacturing industry in this region faces severe challenges. At the same time, the central and western regions and underdeveloped coastal areas show great potential, providing good conditions for the development of traditional manufacturing industries. The central and western regions offer investors a greater choice in terms of production factors, such as taxation, land, and capital, to encourage investors to transfer industries (Chen et al., 2018). The spatial planning and control policies of local governments are the main factors affecting the suburbanization of Chinese urban industries (Zhang et al., 2018). The interwoven relationship between government and market forces has been increasingly understood in the literature. In this interwoven relationship, local governments play a leading role, while market forces are less important (Zhang et al., 2018). The findings of this research also fully verify the views in the existing literature and theoretical assumptions.

5.2 Future development and policy implications

The case area was converted from industrial land to residential and commercial land, changing the original urban fringe area to the core area of the city; the environment has also greatly improved. The transformation encompasses change from an old industrial base to a comprehensive service-oriented new urban area with an ecological and livable riverside. The Nanjing Yanziji Area will establish a scenic belt and a tourist landscape belt along the Yangtze River, and a high-quality residential life and leisure belt. The field investigation found that following the renovation, this area was utilized by Nanjing residents for walking, leisure, and tourism. Profits from land transactions have become an important source of government revenue, and local governments have shown a willingness to push up land prices through expropriation, distribution, or transfer of their monopoly power (Liu and Lin, 2014). Local governments can transfer land to developers to collect land transfer fees and invest the land transfer fees in infrastructure to stimulate economic growth (Yuan et al., 2019; Ruan et al., 2020). Following the renovation of the case area, there have also been increasing housing prices in these areas, and land value has undergone a fundamental change from industrial output to residential services. This is in line with research on land value gains and games (Gao and Chen, 2020).

Over the past two decades, there has been a dramatic increase in the expansion of industrial land, accompanied by rapid economic growth and urbanization, as discussed in the Chinese literature, particularly in terms of

political incentives, including the promotion of officials (He et al., 2019). Thus, politicians and government officials are no longer engaged in the pure pursuit of economic growth, but are focusing on high-quality sustainable development that protects the environment and improves citizens' quality of life. Since 2018, the central government has issued strict environmental regulations for the chemical industry of the Yangtze River. Nanjing is one of the biggest cities along the Yangtze River, and leads the implementation of national environmental regulations in terms of urban development and transformation of old industrial land. The city will also guide the policy formulation and practices in other small-and medium-sized cities. In the layout of polluting industries such as chemical companies, small and medium-sized cities must fully consider the spatial distance and expansion direction from the main urban area of the city to avoid mutual interference after urban expansion.

6 Conclusions

China' significant urban and industrial transformation in recent years offers an indispensable and valuable case for developing countries. This research uses a old chemical industy area in megacity of China as an example to study the transformation and adjustment of chemical industry concentration areas in urban areas. Based on industrial enterprise data, historical document data, and interview surveys, we found that the Yanziji Chemical Area is experiencing industrial suburbanization. With the expansion of urban areas, chemical companies have gradually moved to suburban chemical parks or other surrounding small cities, and the original industrial land has also been converted into residential and commercial land. The entire historical process of the old industrial area and the chemical industry it hosted was formed under the combined effect of different influencing factors. In the first stage, during the rise and prosperity of the chemical industry zone, traditional factors played a role, including geographic location, transportation, industrial agglomeration, and foreign investment. In the second stage, during the decline and transformation period of the chemical industry zone, local government issued strong, enforceable policies in a mandatory and efficient manner during the process of determining the relocation and transformation of enterprises. Market participation also played a role, reflected in the intervention of real estate capital in land replacement. The findings from this study demonstrate that the key to the suburbanization of urban pollution industries and the transformation of old industrial areas is land planning, environmental regulation, and industrial control policies of local governments. Traditional and emerging forces such as geographic location and land prices are in a subordinate position.

This research contributes to the literature in the following ways. First, unlike existing research, research on manufacturing suburbanization and industrial land restructuring focuses on the entire industrial sector of the city. This research enhances the understanding of the development history and reconstruction of chemical industry clusters and plots within megacities at a finer geographic scale. Particular emphasis was placed on the dynamics underpinning the forces and factors in this process, which enriches the theory of urban renewal and sectoral industrial location. Second, we proposed a conceptual framework of space and land conversion based on the life cycle of the chemical industry and agglomeration areas, with special attention on the government's role. The empirical evidence of the study has well verified the hypothesis and theoretical construction. Third, as a supplement to research on industrial suburbanization and industrial land renewal, this research estimates the time scale at approximately 100 yr. This helps to demonstrate the historical stages applicable to the formation and change of industrial land and reveals the mutual influence and correlation effects between the industrial zone and the city.

Acknowledgment

We acknowledge all the interviewees sharing their information and knowledge. We are also grateful for the guidance of Professor Yu Xiaogan and Professor Wang Lei, and the comments of the journal's anonymous reviewers.

References

Asl-Najafi J, Yaghoubi S, 2021. A novel perspective on closed-loop supply chain coordination: product life-cycle approach. *Journal of Cleaner Production*, 289: 125697. doi: 10.1016/j.jclepro.2020.125697

Boyang G, Weidong L, Dunford M, 2014. State land policy, land

markets and geographies of manufacturing: the case of Beijing, China. *Land Use Policy*, 36: 1–12. doi: 10.1016/j.landusepol.2013.06.007

Chen C, Reniers G, 2020. Chemical industry in China: The current status, safety problems, and pathways for future sustainable development. *Safety Science*, 128: 104741. doi: 10.1016/j.ssci.2020.104741

Chen W, Shen Y, Wang Y et al., 2018. The effect of industrial relocation on industrial land use efficiency in China: a spatial econometrics approach. *Journal of Cleaner Production*, 205: 525–535. doi: 10.1016/j.jclepro.2018.09.106

Dakkoune A, Vernières-Hassimi L, Leveneur S et al., 2018. Risk analysis of French chemical industry. *Safety Science*, 105: 77–85. doi: 10.1016/j.ssci.2018.02.003

Editor 's Office of Nanjing Chemical Plant Records, 1997. *Nanjing Chemical Plant Records*. Beijing: Publishing House of Local Records. (in Chinese)

Gao J L, Chen W, 2020. Spatial restructuring and the logic of industrial land redevelopment in urban China: III. a case study of the redevelopment of a central state-owned enterprise in Nanjing. *Cities*, 96: 102460. doi: 10.1016/j.cities.2019.102460

Gao J L, Chen W, Liu Y, 2018. Spatial restructuring and the logic of industrial land redevelopment in urban China: II. a case study of the redevelopment of a local state-owned enterprise in Nanjing. *Land Use Policy*, 72: 372–380. doi: 10.1016/j.landusepol.2018.01.006

Gao J L, Chen W, Yuan F, 2017. Spatial restructuring and the logic of industrial land redevelopment in urban China: I.theoretical considerations.. *Land Use Policy*, 68: 604–613. doi: 10.1016/j.landusepol.2017.07.021

Hayter R, 1997. *The Dynamics of Industrial Location: The Firm the Factory and the Production System.* Chichester: John Wiley.

He C F, Wei Y D, Pan F, 2007. Geographical concentration of manufacturing industries in China: the importance of spatial and industrial scales. *Eurasian Geography and Economics*, 48(5): 603–625. doi: 10.1080/00343400701543272

He C F, Wei Y D, Xie X, 2008. Globalization, institutional change, and industrial location: economic transition and industrial concentration in China. *Regional Studies*, 42(7): 923–945. doi: 10.2747/1538-7216.48.5.603

He Q S, Xu M, Xu Z K et al., 2019. Promotion incentives, infrastructure construction, and industrial landscapes in China. *Land Use Policy*, 87: 104101. doi: 10.1016/j.landusepol.2019.104101

Hu Y, Lu B, Wu J, 2019. Value capture in industrial land renewal under the public leasehold system: a policy comparison in China. *Land Use Policy*, 84: 59–69. doi: 10.1016/j.landusepol.2019.02.038

Hudson R, 2002. Changing industrial production systems and regional development in the New Europe. *Transactions of the Institute of British Geographers*, 27: 262–281. doi: 10.1111/1475-5661.00055

Jiahuey Y, Liu Y, Yu Y, 2019. Measuring green growth performance of China 's chemical industry. *Resources, Conservation and Recycling*. 149: 160–167. doi: 10.1016/j.resconrec.2019.03.025

Kapitsinis N, 2018. Interpreting business mobility through socio-economic differentiation Greek firm relocation to Bulgaria before and after the 2007 global economic crisis. *Geoforum*, 96: 119–128. doi: 10.1016/j.geoforum.2018.08.002

Kyriakopoulou E, Xepapadeas A, 2013. Environmental policy, first nature advantage and the emergence of economic clusters. *Regional Science and Urban Economics*, 43(1): 101–116. doi: 10.1016/j.regsciurbeco.2012.05.006

Leaf M, 2002. A tale of two villages: globalization and peri-urban change in China and Vietnam. *Cities*, 19: 23–31. doi: 10.1016/S0264-2751(01)00043-9

Liu T, Lin G C S, 2014. New geography of land commodification in Chinese cities: uneven landscape of urban land development under market reforms and globalization. *Applied Geography*, 51: 118–130. doi: 10.1016/j.apgeog.2014.04.005

Liu Y, Yue W Z, Fan P L et al., 2016. Financing China's suburbanization: capital accumulation through suburban land development in Hangzhou. *International Journal of Urban & Regional Research*, 40(6): 1112–1133. doi: 10.1111/1468-2427.12454

López-Navarro M A, Tortosa-Edo V, Castán-Broto V, 2018. Firm-local community relationships in polluting industrial agglomerations: how firms ' commitment determines residents ' perceptions. *Journal of Cleaner Production*, 186: 22–33. doi: 10.1016/j.jclepro.2018.03.071

Mao X, Huang X Y, Song Y J et al., 2020. Response to urban land scarcity in growing megacities: urban containment or intercity connection? *Cities*, 96: 102399. doi: 10.1016/j.cities.2019.102399

Nicolaides B, 2006. Review of lewis, manufacturing suburbs: building work and home on the metropolitan fringe. *Pacific Historical Review*, 75(1): 169–170. doi: 10.1525/phr.2006.75.1.169

Niu Fangqu, Yang Xinyu, Wang Fang, 2020. Urban agglomeration formation and its spatiotemporal expansion process in China: from the perspective of industrial evolution. *Chinese Geographical Science*, 30(3): 532–543.

Ruan F L, Yan L, Wang D, 2020. The complexity for the resource-based cities in China on creating sustainable development. *Cities*, 97: 102571. doi: 10.1016/j.cities.2019.102571

Shen J, Wang S, Liu W et al., 2019. Does migration of pollution-intensive industries impact environmental efficiency? evidence supporting pollution 'Haven Hypothesis'. *Journal of Environmental Management*, 242: 142–152. doi: 10.1016/j.jenvman.2019.04.072

Shen J, Wu F L, 2013. Moving to the suburbs: demand-side driving forces of suburban growth in China. *Environment & Planning A: Economy and Space*, 45(8): 1823–1844. doi: 10.1068/a45565

Sun Y F, Ma A B, Su H R et al., 2020. Does the establishment of development zones really improve industrial land use effi-

ciency? implications for China 's high-quality development policy. *Land Use Policy*, 90: 104265. doi: 10.1016/j.landusepol.2019.104265

Thompson J, Miller E, 1978. Manufacturing: a study of industrial location. *Geographical Review*, 68: 493. doi: 10.2307/214224

Tian L, Liang Y, Zhang B, 2017. Measuring residential and industrial land use mix in the peri-urban areas of China. *Land Use Policy*. 69: 427–438. doi: 10.1016/j.landusepol.2017.09.036

Wang L, Acheampong R A., He S, 2020. High-speed rail network development effects on the growth and spatial dynamics of knowledge-intensive economy in major cities of China. *Cities*, 105: 102772. doi: 10.1016/j.cities.2020.102772

White M, 1976. Firm suburbanization and urban subcenters. *Journal of Urban Economics*, 3(4): 323–343. doi: 10.1016/0094-1190(76)90033-4

Wu Y Y, Wei Y D, Li H, 2020. Firm suburbanization in the context of urban sprawl: neighborhood effect and sectoral difference. *The Professional Geographer*, 72(4): 598–617. doi: 10.1080/00330124.2020.1750437

Xi Y, 2008. *Nanjing Urban Planning Records*. Nanjing: Jiangsu People's Publishing House. (in Chinese)

Xie H, Chen Q, Lu F et al., 2018. Spatial-temporal disparities, saving potential and influential factors of industrial land use efficiency: A case study in urban agglomeration in the middle reaches of the Yangtze River. *Land Use Policy*, 75: 518–529. doi: 10.1016/j.landusepol.2018.04.027

Xu X, Shao Y, 2014. The rebirth of the cradle of chemical industry. China environment news,http://49.5.6.212/html/2014-08/29/content_16641.htm.

Yang Fiona Fan, Hu Fox Zhiyong, Wang Yuhua, 2020. Post-industrial economic restructuring and wage inequality in urban China, 2003−2015: a sectoral perspective. *Chinese Geographical Science*, 30(3): 516–531. doi: 10.1007/s11769-020-1125-0

Yuan F, Wei Y D, Xiao W Y, 2019. Land marketization, fiscal decentralization, and the dynamics of urban land prices in transitional China. *Land Use Policy*, 89: 104208. doi: 10.1016/j.landusepol.2019.104208

Zhang L, Yue W, Liu Y et al., 2018. Suburban industrial land development in transitional China: Spatial restructuring and determinants. *Cities*, 78: 96–107. doi: 10.1016/j.cities.2018.02.001

Zhang Wenzhong, Dong Keguo, Tian Shanchuan, 2009. Development and evolution of spatial distribution of Chinese petrochemical industry. *Geographical Research*, 28(5): 1378–1388. (in Chinese)

Zhang Z F, Liu J Z, Gu X K, 2019. Reduction of industrial land beyond urban development boundary in Shanghai: differences in policy responses and impact on towns and villages. *Land Use Policy*, 82: 620–630. doi: 10.1016/j.landusepol.2018.12.040

Zhao P J, Hu H Y, 2019. Geographical patterns of traffic congestion in growing megacities: big data analytics from Beijing. *Cities*, 92: 164–174. doi: 10.1016/j.cities.2019.03.022

Zheng D, Shi M J, 2018. Industrial land policy, firm heterogeneity and firm location choice: Evidence from China. *Land Use Policy*, 76: 58–67. doi: 10.1016/j.landusepol.2018.04.040

Zhou L, Tian L, Gao Y, et al. , 2019. How did industrial land supply respond to transitions in state strategy? An analysis of prefecture-level cities in China from 2007 to 2016. Land Use Policy, 87: 104009. 10.1016/j. landusepol. 2019.05. 028

Zhu J M, 2000. The impact of industrial land use policy on industrial change. *Land Use Policy*, 17(1): 21–28. doi: 10.1016/S0264-8377(99)00038-1