Industrial land supply at different technological intensities and its contribution to economic growth in China: A case study of the Beijing-Tianjin-Hebei region

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ABSTRACT

Industrial land supply, as an important governmental tool in China, has both economic and political connotations. Using the Beijing-Tianjin-Hebei (BTH) region as a study area, this paper examines local governments’ behavior in supplying industrial land at different technological intensities and its contribution to economic growth from 2007 to 2018. The results are as follows: (1) As time passed, basic industrial land (BIL) supply became increasingly agglomerated, while technology-intensive industrial land (TIL) supply gradually dispersed. (2) A TIL supply corridor could be identified in the central part of the BTH region. (3) The contribution of TIL supply to local economic growth was significantly greater than that of BIL supply. (4) There existed a ‘zero-sum inter-regional linkage effect’ among neighboring counties, and TIL supply made a greater contribution than BIL supply in the zero-sum game. Finally, important implications for industrial land supply and regional development policies in the BTH region are proposed.

1. Introduction

Land is not only the spatial carrier of socioeconomic activities but also one of the key tools of local governments in terms of both urban management and economic promotion (Dale, 1997; Zhu, 2004; Williamson et al., 2016; Ooi et al., 2011; Solé-Ollé and Viladecans-Marsal, 2012; Liu, 2018; Wang et al., 2019; Xu and Yang, 2019), especially for developing countries in the process of rapid urbanization and industrialization (Bao et al., 2019; Gu et al., 2019). Over the past three decades, China has adopted a model of land-centered growth (Zhang, 2000; Heikkila, 2007; Ye and Wu, 2014). From 1990 to 2018, the gross area of construction land in China grew from 11,608km² to 55,156km², an impressive growth rate of 375%. Industrial land played an essential role in city growth (Liu et al., 2014), accounting for more than 20% of the total growth. China, widely known as the “world factory”, is still experiencing a rapid increase in industrial land supply. From 2007 to 2018, the increment of industrial land supply was 15,294.02km², accounting for 26.23% of the total land supply, which was much higher than that of residential or commercial land.

Industrial land supply is of great significance for China for the following three reasons: (1) it offers opportunities to bring about a steady tax revenue stream, contributing to local public finance (Tian and Ma, 2009; Wu et al., 2019); (2) it provides political achievements for the promotion of officials (Ding and Lichtenberg, 2011; Cai, 2017; Wang et al., 2020); (3) it vigorously promotes urbanization by developing fixed asset investments, increasing infrastructure construction, generating employment opportunities, etc. (Tao et al., 2016; Zhang et al., 2019). Therefore, industrial land supply is regarded as an indispensable tool for local economic growth.

A voluminous amount of existing literature has discussed industrial land supply from a variety of perspectives, such as supply incentives (Ding, 2002; Lichtenberg and Ding, 2009), misallocation with commercial and residential land supply (Li et al., 2016; Huang and Du, 2017a,b), and government intervention in the land market (Zhu, 1999; Tian and Ma, 2009; Wang and Yang, 2016; Gao et al., 2019). Some scholars regard industrial land supply as the key to understanding China’s development issues, such as economic restructuring, intergovernmental relations, and the optimization of the urban-rural spatial
structure (Yew, 2012; Huang and Du, 2017a,b; Long and Qu, 2018; Liu et al., 2018). However, to the best of our knowledge, most existing research has been conducted at the national or intra-city scale, while a limited number of studies have focused on regions, especially in urban agglomerations, which are deemed as the ultimate spatial form of China’s urbanization (Fang and Yu, 2017). Meanwhile, in recent years, China has upgraded its industrial structure and launched the National Innovation-driven Development Strategy, and therefore, technological change has become the prime-mover for keeping the industrial economy competitive (Huang et al., 2017). However, few studies have focused on the differences in land supply characteristics and the economic contribution of industries at different technological intensities.

In this study, we take the Beijing-Tianjin-Hebei (BTH) region, one of the three most dynamic urban agglomerations in China, as the study area and examine the local governments’ behavior in supplying industrial land at different technological intensities and its contribution to economic growth. This study collects information on 27,615 pieces of industrial land supplied by 202 county-level governments from 2007 to 2018 and divides the industrial land into two categories: basic industrial land (BIL) and technological-intensive industrial land (TIL). The following research questions are investigated:

1. What are the spatio-temporal characteristics of BIL and TIL supply in the BTH region?
2. What are the contributions of industrial land supply, including two types of land, to local economic growth?
3. Does the industrial land supply of local government have a spillover effect on the economic growth of neighboring counties?

The remainder of this paper is structured as follows. Section 2 reviews the extant literature on industrial land supply. Section 3 illustrates the study area, data, and methodology of this research. The following two sections present the research results and discussion. The final section concludes the paper with the direction future research should take.

2. Industrial land supply as a governmental tool of economic growth and regional competition in China

In China, since the tax-sharing reform in 1994, 75% of tax revenue from manufacturing has gone into the coffers of the central government. In return, local governments have been allowed to keep the majority of Land Use Rights conveyance fees. In such a context, industrial land supply becomes a key governmental tool and has political and economic connotations since it closely relates to investment and economic growth.

2.1. Industrial land supply behavior of local governments in regional competition

Under political centralization and fiscal decentralization, local state corporatism has emerged in China, making economic growth the primary task of administrators and the core indicator of top-down performance evaluations. As the main contributor of tax revenue and an indispensable tool for local governments to promote economic growth, industrial investments are not necessarily fixed on any one location (Tao et al., 2010; Zhou et al., 2019). Many industrial enterprises target not only local customers but also the regional and global markets. They do not need to fix their investment destination to a specific region. Instead, they tend to compare production costs, business environment, and investment policies of alternative cities when deciding upon a location. Local governments, therefore, often propose various industrial land supply strategies to take the lead in the fierce regional competition to attract an industrial enterprise.

The strategy of ‘attracting investment through low-cost land’ has garnered extensive attention. Numerous scholars have proposed that local governments prefer to attract industrial enterprises through low-price and large-scale supply of industrial land so as to take the lead in expected tax source stabilization and economic development (Lichtenberg and Ding, 2009; Tao et al., 2016; Huang and Du, 2017a,b). Wu et al. (2014) and Li et al. (2018) further pointed out that neighboring cities often participate in the low-price competition in industrial land supply. For a certain piece of land, if one party loosens the supply price, the subsequent price would spiral downward in a dynamic multi-player game. Yang et al. (2014) and Zhang et al. (2019) found that there is not only a low-price competition between local governments but also a bottom-line race to attract investment at the expense of investment quality for large-scale industrial land supply.

Recently, some researchers have discussed supply modes for different types of industrial land. Yang and Yang (2016) found that facing urgent economic growth pressure, local governments often supply more industrial land to state-owned enterprises (SOEs); and that the growth rate of industrial land supply is larger in cities with a higher proportion of SOEs than in others. Zhang et al. (2017) and Yang and Luo (2018) pointed out that local governments would increase land supply to those listed as key industries in the national and provincial Five-Year Plans. Yang et al. (2018a) believe that if a city is designated as a low-carbon economy pilot city, the scale of energy-intensive industrial land supply will decrease rapidly. Tang et al. (2018b) found that if a city leader is over 57 years old or has a tenure of more than 4 years, he/she would be more inclined to enhance the scale of energy-intensive industrial land supply to gain immediate political promotion opportunities through short-term economic benefits, even at the expense of possible future environmental problems.

2.2. Effects of industrial land supply on economic growth

Industrial land supply has played an essential role in China and has brought about a series of problems. First, the economic efficiency of industrial land use is questioned by many scholars (Bai et al., 2014; Liu et al., 2014). Some scholars believe that low-price and large-scale industrial land supply results in local governments’ pursuit of urbanization and industrialization; and that it not only violates the rule of the market economy but also tends to cause industry homogenization in many cities, leading to universally low land use efficiency (Choy et al., 2013; Li et al., 2016; Zhang et al., 2017; Chen et al., 2018). Moreover, the relationship between industrial land supply, development zones, and urban sprawl has also come into focus and shown to be inefficient. For example, Yew (2012) agreed that the oversupply of underpriced industrial land causes unnecessary waste of land resources in many development zones. Liu et al. (2014) found that around 1/3 of the development zones are left unused, which is characterized as “ratification without construction, more occupation than construction”. Liu et al. (2018) further proposed the concept of “industrial sprawl”, which is characterized by numerous leapfrogged development zones, inefficient land supply, and slow economic growth.

Secondly, many researchers have focused on whether industrial land supply is an effective policy instrument for economic and industrial development. Aghion et al. (2015) and Wang and Yang (2016) found that large-scale land supply can lead to the effective concentration of capital and labor and consequent promotion of industrial productivity, especially in cities facing strong competition. Dong et al. (2019) believed that industrial land supply is conducive to urban and regional innovation. However, some scholars argued that there are negative effects of China’s low-price and large-scale industrial land supply mode. For example, this mode leads to a backward industrial structure dominated by low-end industries, inhibits industrial transformation as well as technological innovation (Li and Luo, 2017; Yu et al., 2018), and restricts industrial optimization (Chen et al., 2018). Shu et al. (2018) and Xie et al. (2019) even argued that it has limited the land supply scale of producer services, leading to a lack of producer service agglomeration.

As noted above, previous research has presented much discussion on the causes and consequences of industrial land supply in China. However, studies on the spatio-temporal characteristics of industrial land
supply are insufficient, especially those on the scale of urban agglomerations. Meanwhile, several studies attempt to reveal the effect of industrial land supply on economic growth, but little research focuses on the economic contribution gaps between different types of industrial land supply. In addition, a large body of existing literature has discussed the impact of industrial land supply on local development, but there have been limited studies discussing the role of inter-city relationships in industrial land supply. This study attempts to fill these gaps by exploring the spatio-temporal characteristics and economic contributions of industrial land supply at different technological intensities within the BTH region.

3. Study area, data, and method

3.1. Study area

The BTH region consists of three provincial administrative units (e.g., Beijing, Tianjin, and Hebei Province) and covers a total area of 218,000 km$^2$ (Fig. 1). In 2018, its permanent population was 112.70 million, accounting for 8.08% of the national total, and its GDP reached 8.54 trillion, constituting 9.29% of the national total. Since 2014, the coordinated development of the BTH region has been regarded as a national strategy.

The industrial economy has dramatically contributed to the economic growth of the BTH region. Even Beijing, a service industry-dominant city, has maintained rapid growth in high-tech industrial enterprises, output value, and employees during recent years. Tianjin is recognized as one of nationally advanced manufacturing centers in the 13th Five-Year Plan. Hebei Province, as a major industrial province, has long ranked as one of leading provinces in China in terms of total industrial output value.

3.2. Data sources

In this study, all 202 districts, counties, and county-level cities (abbreviated to “counties” hereafter) in the BTH region are selected as samples. In addition, two types of county-level panel data are collected: industrial land supply data and socioeconomic data.

Industrial land supply data from 2007 to 2018 are collected from the Land China website (www.landchina.com). Since 1 August 2006, the central government of China has required that local governments publish all supply cases of state-owned land on the Land China website, which enables us to obtain detailed information of each case of industrial land supply in the BTH region over the past twelve years. After data cleaning, 27,615 industrial land supply cases between 2007 to 2018 are collected. Then, according to the industry type of land renter, all supplied industrial land is divided into BIL and TIL. According to industry categorization standards proposed by international organizations like OECD and EU (OECD, 2011; EPO, 2013) and the Chinese National Industries Classification (GB/T 4754-2017), we group eight kinds of industries and five kinds of services as technology-intensive industries, while others are regarded as basic industries (Table 1).

The socioeconomic data of counties are collected from the China city statistical yearbook, the statistical yearbooks of Beijing, Tianjin, Hebei Province, and some prefecture-level city statistical yearbooks. Note that there were 202 counties at the end of 2018 in the BTH region, and after removing those samples with incomplete information, we kept 180

### Table 1

<table>
<thead>
<tr>
<th>Technology intensive industries</th>
<th>Technology intensive services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceutical industries</td>
<td>Internet services</td>
</tr>
<tr>
<td>Special equipment industries</td>
<td>Software and information technology services</td>
</tr>
<tr>
<td>Automobile industries</td>
<td>Research and development services</td>
</tr>
<tr>
<td>Transportation equipment industries</td>
<td>Special technical services</td>
</tr>
<tr>
<td>Computer, communication, and other electronic equipment industries</td>
<td>Telecommunication, TV, and satellite transmission services</td>
</tr>
<tr>
<td>Photographic equipment industries</td>
<td></td>
</tr>
<tr>
<td>Electrical machinery and equipment industries</td>
<td></td>
</tr>
<tr>
<td>Instrument industries</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 1. Location of the BTH region in China.](image-url)
3.3. Research Method

3.3.1. Global and local Moran’s I indices for the identification of spatial autocorrelation

The spatial autocorrelation of industrial land supply in the BTH region is analyzed by using Moran’s I indices. First, the Global Moran’s I is used to describe the spatial agglomeration degree of industrial land supply. The formula is as follows:

\[
\text{Global Moran’s } I = \frac{\frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \overline{x}) (x_j - \overline{x})}{\sqrt{\left( \frac{1}{n} \sum_{i=1}^{n} (x_i - \overline{x})^2 \right) \left( \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \right) \left( \frac{1}{n} \sum_{i=1}^{n} (x_i - \overline{x})^2 \right)}}
\]

(1)

where \(x_i\) is the area of supplied industrial land in county \(i\); \(\overline{x}\) is the average area of supplied industrial land in all counties; \(n\) is the number of observations; \(w_{ij}\) is the spatial weight between county \(i\) and county \(j\), which equals 1 if county \(i\) and county \(j\) are adjacent and 0 otherwise. \(w_{ij}\) is the element of \(W\), a contiguity-based spatial weight matrix (Zhou et al., 2019; Yang et al., 2020a,b).

If Global Moran’s \(I\) \(\in (0, 1]\), we can conclude that a positive spatial correlation exists in areas of supplied industrial land, meaning that counties with similar land supply scales are agglomerated. The larger the Moran’s \(I\) value, the higher the degree of agglomeration. Conversely, when Global Moran’s \(I\) \(\in [-1, 0)\), it means that spatial correlation is negative in areas of supplied industrial land. The smaller the Moran’s \(I\) value is, the higher the degree of dispersion.

The standardized statistic \(Z\) is used to test the statistical significance of the Global Moran’s \(I\), and its formula is as follows:

\[
Z = \frac{I - E(I)}{\sqrt{\text{Var}(I)}}
\]

(2)

where \(E(I)\) is the expectation of Global Moran’s \(I\) and \(\sqrt{\text{Var}(I)}\) is the variance of Global Moran’s \(I\). If \(|Z| > 1.65\) (1.96), spatial autocorrelation is significant at the 10% (5%) level (Anselin, 1995; McMillen, 2004).

Local Moran’s \(I\) is often used to identify the spatial agglomeration pattern of industrial land supply in different counties, which is calculated as follows:

\[
\text{Local Moran’s } I_i = \frac{n(\overline{x} - \overline{y}) \sum_{j=1}^{n} w_{ij} (y_i - \overline{y})^2}{\sum_{i=1}^{n} (x_i - \overline{y})^2}
\]

(3)

where Local Moran’s \(I_i\) is the Local Moran’s \(I\) at point \(i\), and all the other variables are as defined in Eq. (1). The significance level of Local Moran’s \(I_i\) is measured by \(Z(I_i)\). When the Moran’s \(I\) value is positive and \(Z(I) > 1.65\), the county is given a High-High (HH) designation. This means that the county has an above-the-mean area of supplied land, and the average area of its neighboring counties is also above the (global) mean. When the Moran’s \(I\) value is positive and \(Z(I) < -1.65\), the county is given a Low-Low (LL) designation. This means that the county has a below-the-mean area of supplied land, and the average area of its neighboring counties is also below the (global) mean. When the Moran’s \(I\) value is negative and \(Z(I) > 1.65\), the county is given a High-Low (HL) designation. This means that the county has an above-the-mean area of supplied land, but the average area of its neighboring counties is below the (global) mean. When the Moran’s \(I\) value is negative and \(Z(I) < -1.65\), the county is given a Low-High (LH) designation. This means that the county has a below-the-mean area of supplied land, but the average area of its neighboring counties is above the (global) mean (Zhou et al., 2019; Gu et al., 2020; Shen and Yu, 2020).

3.3.2. Dynamic panel autoregressive (DPA) model

Over the past half-century, many scholars have extended the production function to include the land input factor (Nichols, 1970; Nordhaus et al., 1992; Tideman, 1995; Romer and Romer, 2002; Mo, 2018). According to Feng et al. (2008) and Chen et al. (2018), we establish a production function as follows.

\[
Y = AL^\alpha N^K^\beta \eta
\]

(4)

where \(\alpha + \beta + \gamma = 1\) (assuming that the production function has constant returns to scale); \(Y\) is the total output of the economy; \(L\) is newly added land input; \(N\) is labor input; \(K\) is capital input; and \(A\) is technological progress. Taking the natural logarithms on both sides of the above formula, we get:

\[
y = a + \alpha \ln n + \beta \ln k + \gamma \ln \eta
\]

(5)

where \(y, \alpha, \beta, \gamma, \eta\) are the natural logarithm form of \(Y, L, N, K,\) and \(A\), respectively.

According to Eq. (5), we build a basic econometric model:

\[
\ln Y_i = \alpha_1 \ln L_{it} + \alpha_2 \ln N_{it} + \alpha_3 \ln K_{it} + \gamma_i + \delta_i + \mu_{it}
\]

(6)

where \(Y_{it}\) is the GDP of county \(i\) in year \(t\); \(L_{it}\) is additional land input of county \(i\) in year \(t\), which is evaluated by the industrial land supply area (ILA); \(N_{it}\) is the labor input of county \(i\) in year \(t\), which is represented by the number of permanent residents (NPR) in this study (Zengh et al., 2014; Tao et al., 2018) because a more accurate measure, the number of employed persons in the county, is unavailable; \(K_{it}\) is the capital stock of county \(i\) in year \(t\), which is evaluated using the total fixed asset investment (FAI) (Bai et al., 2012; Du and Huang, 2015); \(\alpha_1, \alpha_2, \alpha_3\) and \(\gamma_i\) are the coefficients to be estimated; \(\gamma_i\) is an individual fixed effect; \(\delta_i\) is a time fixed effect; and \(\mu_{it}\) is a random error term. This model controls for both regional individual effects and time effects.

In order to reduce the model’s endogenous problems and setting errors, we introduce a lag term of the dependent variable to establish a DPA model (Arellano and Bond, 1991). Notably, Tao et al. (2010) and Yang et al. (2014) found that most projects enter a two-year factory construction period after obtaining the right to use industrial land, during which the main sources of economic contribution come from fixed investments supporting infrastructure construction; and that the contribution of taxation to economic growth emerges after the completion of most industrial projects. Therefore, this study sets the construction period of the project to two years and includes the industrial land supply scale in lagged one and two year periods in the explanatory variables. Meanwhile, the one-step system Generalized Method of Moments (GMM) is applied to estimate the model, which is expressed as follows:

\[
\ln Y_{it} = \rho_1 \ln Y_{it-1} + \alpha_1 \sum_{u=-2}^{\infty} \ln L_{iu} + \alpha_2 \ln N_{iu} + \alpha_3 \ln K_{iu} + \gamma_i + \delta_i + \mu_{it}
\]

(7)

where \(Y_{it}\) is the GDP of county \(i\) in year \(t\); \(Y_{it-1}\) is the time lag term of \(Y_{it}\); \(L_{it}\) is the ILA of county \(i\) in year \(t\); and other variables are defined as above. In order to investigate the difference in the contributions of BIL and TIL supply to economic growth, we make a simple change to the model:

\[
\ln Y_{it} = \rho_1 \ln Y_{it-1} + \alpha_1 \sum_{u=-2}^{\infty} \ln L_{it, u} + \alpha_2 \ln N_{it, u} + \alpha_3 \ln K_{it, u} + \beta \ln C_{it} + \gamma_i + \delta_i + \mu_{it}
\]

(8)

where BIL and TIL are the BIL supply area (BILA) of county \(i\) in year \(u\); \(C_{it}\) is a set of control variables, including three key socioeconomic variables that are widely considered to contribute to economic growth: (1) the ratio of the secondary industry to the tertiary (RST), which represents the industrial...
structure of counties (Yang et al., 2014; Liang et al., 2016), (2) the ratio of fiscal expenditure to revenue (RFR), which is a key indicator to measure the local fiscal situation (Tao et al., 2010; Du and Huang, 2015). (3) population density (POD), which reflects the intensity of regional economic activity and the size of the local market (Dong et al., 2019); and other variables are defined as above.

### 3.3.3. Dynamic spatial lag of X (DSLX) model

In order to further explore whether the changes in the industrial land supply scale have spillover effects on the economic growth of neighboring counties, we introduce the spatial lag terms of independent variables (industrial land supply area) and build a DSLX model:

\[
\ln Y_{it} = \alpha_1 \ln N_{it} + \gamma_1 W_{it} \ln L_{it, s} + \gamma_2 W_{it} \ln L_{ij, s} + \alpha_2 \ln L_{it, s} + \alpha_3 \ln L_{ij, s} + \alpha_4 \ln N_{it} + \alpha_5 \ln K_{it} + \beta C_{it} + \mu_{it}
\]

where \( \mu_{it} = \tau W_{it} + \epsilon_t; t = t, t-1, t-2; \) and other variables are defined as above. Additionally, the DPA model incorporates \( L_{it, s} \) and \( L_{ij, s} \) in the current year, the lagged one year and the lagged two years into the model. In the dynamic SLX model, however, we include the three variables separately; the reason is that GMM can effectively solve the endogenous problem when estimating the dynamic autoregressive model, but there has yet been no effective solution when estimating the dynamic SLX model.

It is worth noting that the econometric analysis is based on county-level panel data from 2008 to 2017, whose period is slightly different from that of the analysis of spatio-temporal characteristics of industrial land supply. Table 2 presents the definition and descriptive analysis of the main variables.

### 4. Results

Between 2007 and 2018, there were 27,615 industrial land supply cases in the BTH region, covering an area of 94,552 ha, including 22,251 BIL (89,188 ha) and 5364 TIL supply cases (24,256 ha). As Fig. 2 shows, the supply curves of both BIL and TIL present a "rise-fall-rise" pattern. The peak value of BIL supply was in 2009, with an area of 10,737.48 ha, while TIL supply peaked in 2011, with an area of 3198.58 ha. The lowest values of the two types of land supply both occurred in 2016, and the areas were 3582.22 ha and 1152.71 ha, respectively.

#### Table 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Obs</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>Gross domestic product (million yuan)</td>
<td>1797</td>
<td>317.05</td>
<td>755.438</td>
</tr>
<tr>
<td>ILA</td>
<td>Industrial land supply area (ha)</td>
<td>1800</td>
<td>53.25</td>
<td>115.354</td>
</tr>
<tr>
<td>BILA</td>
<td>BIL supply area (ha)</td>
<td>1800</td>
<td>41.50</td>
<td>100.686</td>
</tr>
<tr>
<td>TILA</td>
<td>TIL supply area (ha)</td>
<td>1800</td>
<td>11.75</td>
<td>29.152</td>
</tr>
<tr>
<td>FAI</td>
<td>Total fixed asset investment (million yuan)</td>
<td>1759</td>
<td>197.67</td>
<td>374.319</td>
</tr>
<tr>
<td>NPR</td>
<td>Number of permanent residents (10⁴) person</td>
<td>1753</td>
<td>8.64</td>
<td>19.797</td>
</tr>
<tr>
<td>RST</td>
<td>Ratio of secondary industry to tertiary (%)</td>
<td>1774</td>
<td>1.46</td>
<td>0.895</td>
</tr>
<tr>
<td>RFR</td>
<td>Ratio of fiscal expenditure to revenue (%)</td>
<td>1796</td>
<td>3.62</td>
<td>2.291</td>
</tr>
<tr>
<td>POD</td>
<td>Population density (person/km²)</td>
<td>1751</td>
<td>1923.83</td>
<td>5302.203</td>
</tr>
</tbody>
</table>

1 The county-level panel data do not include data from 2007 and 2018. First, in this study, the econometric analyses introduce the lag term of the dependent variable (ILA, BILA, and TILA). However, the Land China website does not contain all land supply data of 2006, which results in the econometric analyses for 2007. Second, as of now, the county-level socioeconomic data in 2018 have not yet been released, so we cannot conduct econometric analysis for 2018.

### 4.1. Spatio-temporal characteristics of industrial land supply

In China, the Five-Year Plan is essential for policy-making of local governments since it predominately decides the layout of key infrastructure facilities. Since 2011 and 2015 are the years when the 12th and 13th Five Year Plans of land and resources were created, respectively, we analyze industrial land supply characteristics in three periods: 2007-2010, 2011-2014, and 2015-2018.

#### 4.1.1. Spatial autocorrelated characteristics of BIL and TIL supply

According to Table 3, from 2007 to 2018, BIL supply is positively and significantly spatially autocorrelated, which means that counties in the BTH region with a similar (high or low) land supply scale had been spatially agglomerated. Moreover, the Global Moran’s I value of BIL supply increases from 0.24 in 2007-2010 to 0.34 in 2015-2018, so we can conclude that the agglomeration degree increases over time. Meanwhile, TIL supply also shows characteristics of spatial agglomeration in the BTH region, although the agglomeration degree declined gradually; and the Global Moran’s I value decreased from 0.27 in 2007-2010 to 0.19 in 2015-2018.

#### 4.1.2. Spatio-temporal pattern of BIL and TIL supply

Fig. 3 shows the spatio-temporal pattern of BIL and TIL supply. It indicates that the scale of BIL supply decreased from coastal to inland regions over time (Fig. 3). The majority of coastal counties in Tianjin, Tangshan, and Cangzhou formed the single large scale HH county clusters during each period. In other words, the bay area, in which three major ports in the BTH region (Tangshan, Tianjin, and Huanghual Ports) are situated, attracted a large number of basic industrial projects from 2007 to 2018. In addition, the Beijing government gradually restricted investment in basic industrial projects and substantially reduced the scale of BIL supply, especially from 2015-2018, a period in which all counties entered LL county clusters. During the same period, the supply scale of BIL in neighboring counties also experienced a similar downward trend.

Compared with that of BIL supply, the change in spatial characteristics of TIL supply is more significant. The main form of the HH county clusters had changed from dumbbell-shaped to pistol-shaped and then to crescent-shaped, and the distribution mode of the LL county clusters had transformed from macro dispersion and micro concentration to micro dispersion and macro concentration. The “bay area” still played an important role in the spatio-temporal change process of TIL supply. Meanwhile, we find some counties in Beijing, Baoding, Langfang, and Shijiazhuang attach great importance to TIL supply, which can be seen in HH county clusters over different periods. Even from 2015-2018, when the supply focus heavily favored the bay area, the supply scale of Daxing (belonging to Beijing) and Xushui (belonging to Baoding) still ranked in the top 10 in the BTH region.

#### 4.1.3. Spatio-temporal characteristics of TIL supply share of total industrial land

As noted above, compared with BIL supply, TIL supply had not only highly agglomerated in the “bay area” but also presented a South-North ward trend.

Fig. 5 reveals the spatio-temporal characteristics of TIL supply proportion. Interestingly, the spatial characteristics of TIL supply proportion were quite different from those of the two industrial land supply types between 2007 to 2018 (see Figs. 3 and 4). High-value agglomeration did not cluster in the bay area. Instead, some coastal counties were even in LL or LH county clusters. However, a 300-kilometer-long corridor, with a high proportion of TIL supply in several counties in Beijing, Baoding, Langfang, and Shijiazhuang, had sprung up in the middle of the BTH region. Also, the average TIL supply proportion in the
4.2. Contribution of industrial land supply to economic growth

4.2.1. Local economic contribution of industrial land supply

To reveal the role of industrial land supply in shaping economic growth, we regress the GDP (in natural logarithm form) onto the industrial land supply scale of these counties. The results are reported in Table 4. After controlling other exogenous variables, all coefficients of ILA are positive and significant (column 1), indicating that increasing industrial land supply could effectively promote regional economic growth. Then, the effects of BIL and TIL supply on the counties’ GDP are evaluated separately. According to column 2, besides the coefficient of one year lagged BILA, other coefficients are all positive and significant; and a 1% growth in TILA would lead to 0.068%, 0.048%, and 0.074% growth in GDP in the current, second, and third years, respectively, while a 1% growth in BILA would only lead to 0.032% and 0.014% growth in GDP in the current and third years, respectively. The results not only indicate that TIL supply played a more important role in regional economic development but also show that the contribution of BIL supply had been somewhat insufficient, compared with the increasing contribution of TIL supply, especially in the third year, when most industrial projects were in operation.

Meanwhile, whether the economic contribution of industrial land supply varies in counties with different supply structures is tested. As column 3 of Table 4 shows, in the counties where TIL supply proportion was less than 30%, the coefficients of the two supply types in the current and lagged two years are positive and significant, and TIL supply had a stronger effect on local economic growth than that of BIL supply. However, in counties where their TIL supply proportion was over 30%, only the coefficient of BILA in the current year is significant. Considering the differences in the development stages of counties in the BTH region (column 4), we further subdivide the counties with a TIL supply proportion over 30% into two categories, counties in Beijing and Tianjin and counties in Hebei (columns 5 and 6). Interestingly, in counties of Hebei, the supply coefficients of BILA and TILA in lagged two years are statistically significant, and the values both reach the highest across the entire model. That is, these Hebei counties, which paid more attention to TIL supply compared with others, would see not only TIL supply making a greater contribution to the local economy but also BIL supply’s contribution increasing in the third year when most industrial projects were put into production.

4.2.2. Spillover effects of industrial land supply

Table 5 shows the DSLX regression results for testing the impact of the changing industrial land supply scale on the GDP of neighboring counties. The coefficients of six spatially lagged dependent variables are all negative, among which four coefficients are significant, where every increase of 1% in BILA in a given county would lead to a decrease in a neighboring counties’ GDP by 0.018% and 0.011% in the current and second year, respectively, while a 1% growth in TILA in a given county would lead to a decrease in the GDP of a neighboring county by 0.026% and 0.027% in the current and second year, respectively. The results indicate that increasing industrial land supply in one county had a negative spillover effect on the economic growth of neighboring counties. In other words, the competition of land supply among the neighboring counties was a zero-sum game for economic growth. In addition, we find that the negative spillover effect of TIL supply was greater than that of BIL supply. In this zero-sum game of "more land supply of me, less economic growth for you", TIL supply was more important for local governments.

5. Discussion

5.1. Varying evolution paths of agglomeration degree in BIL and TIL supply

This study indicates that from 2007 to 2018, BIL supply tended to be increasingly agglomerated, while TIL supply dispersed gradually. Though the former finding is as expected, the latter finding on TIL supply seems different from our expectations. As a multitude of previous studies suggests, high-tech talents’ pursuit of good idea-exchange environments and tacit-knowledge spillovers often leads to a higher agglomeration degree in industries with more complex technology (Audretsch and Feldman, 1996; Rosenthal and Strange, 2001; Sorenson et al., 2006; Ellison et al., 2010).

On the one hand, with serious environmental pollution plaguing the BTH region in recent years, restricting basic industrial development has been taken as a key measure for many local governments to protect the environment, especially in Beijing and its surrounding cities. This has led BIL (especially that for heavy industries) supply to increasingly concentrate in counties with fewer restrictions on environmental protection (usually underdeveloped counties), increasing the BIL...
agglomeration degree accordingly. On the other hand, as innovation became a new keyword in China’s development, local governments have put substantial efforts into promoting technology-intensive industries. This is evidenced by the fact that over 85% of counties developed at least one technology-intensive industry among the key industries mentioned in the 13th Five Year Plan, so as to achieve a new impetus for economic growth. Regional competition for investment, therefore, has become increasingly intense (He and Hu, 2019), and the spatial pattern of TIL supply has become more dispersed.

5.2. The emergence of a TIL supply corridor

This study reveals a TIL supply corridor emerging in the central part of the BTH region, which includes several counties in Beijing, Baoding, Langfang, and Shijiazhuang, where the TIL supply proportion was higher than the regional average from 2007 to 2018 (Fig. 6). Compared to other counties, local governments within this corridor were more willing to provide industrial land to technology-intensive industrial projects for pioneering the innovation transformation of the industrial economy in the BTH region.

From the California innovation corridor (Alameda to San Diego), to the UK innovation corridor (London to Cambridge), to the G60 technological innovation corridor (Hangzhou to Shanghai), the concept of the innovation corridor has been widely recognized as an important regional innovation model. However, up to now, the BTH region has not yet adopted such a seemingly useful policy, although the TIL supply corridor has similar characteristics to the corridors listed above. First, this corridor has a strong growth pole—Beijing, one of China’s national innovation centers. Some of its counties have outstanding innovation capacity and have created a spillover effect of technological dividends to surrounding areas in the development process. Second, counties in this corridor are conveniently linked by a high-density regional transportation network, which promotes the inter-regional flow of technology, talent, and enterprises. Third, many hi-tech National or Provincial Development Zones are distributed along this corridor, and their leading industries include, but are not limited to, information technology, biological medicine, new energy, and automobile equipment. This provides a platform for technological innovation and technology-intensive enterprise agglomeration. We conjecture that these characteristics not only pave the way towards the emergence of this TIL supply corridor but also indicate that this intercity corridor is now ready for developing or evolving into a distinguished innovation corridor.

5.3. Differentiated contribution of BIL and TIL supply to local economic growth

The DPA regression results show that TIL supply had a significantly greater contribution to local economic growth than BIL supply in the

Fig. 3. Spatio-temporal pattern of BIL supply.
BTH region, especially in the third year, when most industrial projects were in operation.

This finding is in line with our expectations. Many scholars have demonstrated that technological progress is the engine of economic growth and believe that technology-intensive industrial enterprises are more superior than basic ones in many aspects, including technological content, proportion of talents, added-value of products, and scale effect (Keeble et al., 1998; Ellison et al., 2010). Therefore, TIL supply was able to bring greater and more sustainable contributions to regional economic growth. Meanwhile, Huang et al. (2017), Wei and Wang (2014)
In BILA, the growth rate has been rapidly increasing, and this can explain the differences in the economic contribution of BIL and TIL supply in the BTH region.

5.4. Zero-sum inter-regional linkage effect

The SLX regression results show that the increase in the supply scale of BIL and TIL had a negative spillover effect on neighboring counties’ economic growth, regarded as the ‘zero-sum inter-regional linkage effect’. For local governments, each successful industrial land supply case often means an introduction of an enterprise that might promote local economic growth at the cost of their neighboring cities who then lose out on an equal opportunity.

Moreover, compared with BIL supply, TIL supply played a more significant role in the inter-regional zero-sum game, which means that in the BTH region, local governments’ strategy of increasing TIL supply scale could limit the economic growth of neighboring cities. It also reveals that technology-intensive industrial projects have a greater potential to boost the economy — a greater economic loss would in return be suffered if failing to compete for these projects. Moreover, from 2007 to 2018, the industrial land market in the BTH region was dominated by basic industries. Relatively scarce technology and human resources also intensified the impact of increased investment in technology-intensive industrial projects on local economic development.

6. Conclusion

This study focuses on the BTH region, one of China’s most dynamic urban agglomerations and analyzes the local governments’ behavior in supplying industrial land at different technological intensities and their contribution to economic growth from 2007 to 2018. The findings are as

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**Table 4**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In GDP</td>
<td>0.776*** (32.51)</td>
<td>0.779*** (31.59)</td>
<td>0.741*** (25.69)</td>
<td>0.911*** (22.53)</td>
<td>0.781*** (11.31)</td>
</tr>
<tr>
<td>ln BILA</td>
<td>0.013*** (3.77)</td>
<td>0.008*** (3.15)</td>
<td>0.012*** (5.33)</td>
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<td></td>
</tr>
<tr>
<td>ln TILA</td>
<td>0.032** (2.28)</td>
<td>0.028* (1.82)</td>
<td>0.045* (1.86)</td>
<td>-0.007 (1.21)</td>
<td>0.050</td>
</tr>
<tr>
<td>ln BILA</td>
<td>0.010 (1.00)</td>
<td>0.007 (0.60)</td>
<td>0.023 (1.05)</td>
<td>-0.012 (0.72)</td>
<td>0.061</td>
</tr>
<tr>
<td>ln BILA</td>
<td>0.014* (1.79)</td>
<td>0.023*** (2.62)</td>
<td>0.012 (0.65)</td>
<td>0.009 (0.37)</td>
<td>0.051*</td>
</tr>
<tr>
<td>ln BILA</td>
<td>0.068*** (2.73)</td>
<td>0.087*** (2.03)</td>
<td>0.023 (1.03)</td>
<td>0.021 (0.82)</td>
<td>-0.021</td>
</tr>
<tr>
<td>ln TILA</td>
<td>0.048* (1.88)</td>
<td>0.060 (1.52)</td>
<td>0.028 (1.03)</td>
<td>0.009 (0.42)</td>
<td>0.011</td>
</tr>
<tr>
<td>ln TILA</td>
<td>0.074** (2.97)</td>
<td>0.092** (2.20)</td>
<td>0.026 (0.88)</td>
<td>-0.012 (0.50)</td>
<td>0.100**</td>
</tr>
<tr>
<td>ln TILA</td>
<td>0.042*** (3.07)</td>
<td>0.047*** (3.49)</td>
<td>0.058*** (3.57)</td>
<td>0.027 (1.18)</td>
<td>0.101** (2.19)</td>
</tr>
<tr>
<td>ln TILA</td>
<td>0.089*** (2.79)</td>
<td>0.085*** (2.69)</td>
<td>0.074* (1.85)</td>
<td>0.038 (0.94)</td>
<td>0.063 (1.46) (0.75)</td>
</tr>
<tr>
<td>RST</td>
<td>0.000 (0.22)</td>
<td>-0.000 (0.30)</td>
<td>0.000 (0.63)</td>
<td>0.020 (2.10)</td>
<td>(0.43) (1.08)</td>
</tr>
<tr>
<td>RFR</td>
<td>0.006* (2.14)</td>
<td>0.003 (0.93)</td>
<td>-0.001 (0.17)</td>
<td>0.018** (2.51)</td>
<td>0.003 (0.24) (1.58)</td>
</tr>
<tr>
<td>POD</td>
<td>0.115*** (2.61)</td>
<td>0.102** (2.43)</td>
<td>0.068 (1.38)</td>
<td>0.025 (0.59)</td>
<td>-0.034 (0.76) (3.46)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.006 (0.02)</td>
<td>0.129 (0.48)</td>
<td>0.506 (1.63)</td>
<td>0.048 (0.16)</td>
<td>0.929*** (2.72) (1.98)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>1374</td>
<td>1373</td>
<td>908</td>
<td>466</td>
<td>159</td>
</tr>
<tr>
<td>AR1</td>
<td>0.00 (0.00)</td>
<td>0.00 (0.00)</td>
<td>0.00 (0.00)</td>
<td>0.04 (0.04)</td>
<td>0.00</td>
</tr>
<tr>
<td>AR2</td>
<td>0.42</td>
<td>0.38</td>
<td>0.66</td>
<td>0.49</td>
<td>0.12</td>
</tr>
<tr>
<td>Sergen T</td>
<td>0.53</td>
<td>0.54</td>
<td>0.60</td>
<td>0.80</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Note: Standard errors are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

**Table 5**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
<th>Coef. (t-stat.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wln BILA</td>
<td>-0.018*** (-2.86)</td>
<td>-0.026*** (-3.92)</td>
<td></td>
</tr>
<tr>
<td>Wln TILA</td>
<td>-0.011* (1.66)</td>
<td>-0.027*** (-3.99)</td>
<td></td>
</tr>
<tr>
<td>Wln BILA</td>
<td>0.097*** (53.81)</td>
<td>0.093*** (50.34)</td>
<td>0.090*** (46.60)</td>
</tr>
<tr>
<td>County fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of observations</td>
<td>1629</td>
<td>1448</td>
<td>1267</td>
</tr>
<tr>
<td>R²</td>
<td>0.70</td>
<td>0.68</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Note: Standard errors are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
follows: First, the spatio-temporal pattern of BIL supply was increasingly agglomerated, while that of TIL supply showed an opposite trend over different periods. Second, it is observed that a TIL supply corridor emerged in the central part of the BTH region. Third, the contribution of TIL supply to local economic growth was much greater than that of BIL supply. Finally, this study reveals a ‘zero-sum inter-regional linkage effect’ between neighboring counties and finds that TIL supply made a greater contribution than BIL supply in the zero-sum game.

Policy implications for industrial land supply and regional development policies can be drawn from our findings: (1) In the BTH region, the scale of TIL supply was small, and its spatial pattern was gradually dispersed. This is conducive to industrial economic development and land use sustainability (Liu, 2018). Therefore, we suggest that governments work cooperatively to encourage the development of technology-intensive industries and adjust the structure of the overall industrial land supply. Moreover, in order to guide local governments to increase the scale and proportion of TIL supply, some preferential policies should be brought into operation. For example, for counties with an above-the-mean proportion of TIL supply, the city government could give these counties extra land quota and provide more industrial development funds. (2) Innovation is the core development goal of the coordinated development of the BTH region. We, therefore, propose that the three provincial governments give full consideration to the importance of the regional innovation policy and formulate a specific policy based on the TIL supply corridor in the middle of the BTH region. (3) The ‘zero-sum inter-regional linkage effect’ could lead local governments to more actively prepare for attracting outside investment. It, however, may trigger severely vicious competition between regions, especially neighboring ones. Therefore, policies of encouraging cooperation among cities should be proposed to achieve a win-win target. For instance, three provincial governments in the BTH region could jointly formulate a new-added industrial land allocation plan at the county level and establish a regional industry development plan with complementary advantages.

CRediT authorship contribution statement

Lin Zhou: Conceptualization, Methodology, Data curation, Formal analysis, Resources, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. Li Tian: Conceptualization, Writing - review & editing, Supervision, Project administration, Funding acquisition. Yandong Cao: Methodology, Writing - original draft. Linchuan Yang: Writing - review & editing.

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