Government–Directed Urban Growth, Firm Entry, and Industrial Land Prices in Chinese Cities

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Abstract

We examine the effect of a large-scale administrative reorganization in China, where counties are annexed into cities to accommodate urban growth. We present a simple model to illustrate how this annexation may affect firm entry decisions and in turn land market outcomes. Using nationwide data on land-lease transactions, we find that annexation raises industrial land prices in the annexed counties by 7 percent but does not reduce land prices in neighboring counties and central cities. We show that the annexed counties experienced increases in firm entry and investment, offering a plausible mechanism for the effect on industrial land prices.

JEL Classification: R11, R12, R14, R33, R58.

Keywords: Urban growth, industrial land prices, annexation, China.

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1 Introduction

A fundamental question in urban economics is: What is the role of government in the process of urban expansion? The existing literature understands this role mainly as a way to internalize externalities. That is, left alone, market forces fail to fully account for external costs or benefits of urban activities, which creates opportunities for the government to step in to remedy such failures. For example, when urban economists advocate for government policies to curb urban sprawl, or justify urban growth boundaries, density restrictions, and zoning laws, they all use this type of arguments.[1]

In this study, we argue that the role of government goes beyond dealing with externalities. Instead, the government can help improve social welfare by coordinating expectations and reducing uncertainty during urban development. This role can be particularly important in the process of rapid urbanization in developing countries and urban redevelopment in developed countries. While this idea is the main rationale for urban planning, we argue that it has not yet been well explored in urban economics.

Specifically, we will use the term "government directed urban growth" (henceforth DUG) to refer to the type of urban expansion where government plays a role in coordinating expectations. We study the effect of DUG on urban land markets in the context of China. China's governments frequently redefine an administrative unit adjacent to the central city, usually a county-level administrative region, as part of the central city and incorporate it into the jurisdiction of the prefectural-level city government.[2] This study focuses on the effects of a new central-government policy promoting urbanization, which started in the 1990s and became more extensive in the past two decades. We ask how this emerging DUG policy affected industrial land prices and the entry of new firms in annexed areas. Compared to other indicators such as GDP or population that mainly reflect a short-term change, the land price is a more appropriate indicator of impacts because it capitalizes the expected future evolution of the urban economy.

[1] See, for example, Brueckner and Fansler (1983), Brueckner (2000), Glaeser and Kahn (2004), Nechyba and Walsh (2004), Burchfield et al. (2006), Irwin and Bockstael (2007), Schneider and Woodcock (2008), Patacchini and Zenou (2009), Brueckner and Helsley (2011), and Barrington-Leigh and Millard-Ball (2015).

[2] In China, a prefecture government is almost always located in the largest urban area within the prefecture, which is commonly referred to as a prefecture-level city (as opposed to county-level cities within the prefecture). Since a prefecture-level city is always the political and economic center of the prefecture, in this paper we use the two terms *prefecture-level city* and *central city* of the prefecture interchangeably.

China provides a proper context for investigating the impact of urban growth directed by governments. First, China has launched the world's largest DUG program in recent decades. By redefining surrounding counties as urban districts, thereby substantially raising the number of urban districts in the country, China has expanded the spatial scale of prefecture-level cities. By 2019, the last year of our sample period, the number of urban districts had increased to 965, accounting for around one-third of county-level divisions in the whole country.[3] Another reason to focus on China is that the Chinese government collects and publicizes rich micro-data on land transactions across the whole country. This effort is in stark contrast to the data scarcity that has limited research on the impacts of urban sprawl even in developed areas like Europe (Patacchini and Zenou, 2009; Oueslati et al., 2015). The urban-expansion program, with its unprecedented speed and scale, and detailed land transaction data in China provide a rare opportunity for studying the impact of government-directed urban expansion on the local economy.

Our primary data source is administrative data on land transactions in China. The Ministry of Natural Resources makes all land transactions in urban China public, reporting the location and transaction date for each land parcel. Another data source captures the redefinition of surrounding counties as urban districts in prefectural-level cities, which is made available by the Ministry of Civil Affairs. As the political and economic centers of a prefecture, urban districts are directly governed by the prefecture government, whereas surrounding counties can be seen as autonomous regions (Mutreja et al., 2021). We gathered information on all of the county redefinitions and merged it with land transaction data using the location of each land parcel. Finally, we constructed a dataset on all land transactions in the treated counties (i.e., counties redefined as urban districts), existing urban districts, and the neighboring counties of existing urban districts that were not redefined as urban districts during the sample period. The location and transaction date of a land parcel together tell us whether the transaction occurred in an urban district redefined from a surrounding county.

Using the methods of event study and difference-in-differences (DID), we find that the annexation boosts industrial land prices in the treated counties. After controlling for the trend of the industrial land prices in a county, county (district) fixed effects, and

[3] Urban districts, counties, and county-level cities are the three types of county-level divisions in China's administrative system. While urban districts form the central city of prefectures, counties and county-level cities are divisions surrounding the central city. Throughout the paper, we use the term "county" to refer to both counties and county-level cities.

province-year fixed effects, we find that the annexation increases industrial land prices in the treated counties by about 7 percent. The magnitude of this effect is similar whether we use an event study or a DID method using the neighboring counties as the control group. The estimated effects of the annexation on industrial land prices are robust to further controlling for county-level characteristics in the initial year (2010) interacted with year dummies. Moreover, we did not find that the annexation has any significant impacts on industrial land prices in the original central city or the neighboring regions that are adjacent to central cities but were not annexed by central cities, suggesting that the estimated price effects do not result from spillover effects of the annexation.

We also explore the mechanisms behind the land price effects of the annexation by showing that the annexation leads to entry of firms in the annexed county. By redefining a county as an urban district and merging it with the central city of the prefecture, the annexation induces firms to set up operations in the new district. We also find some evidence that annexed counties experience more investment in fixed assets following the reform. Both these effects suggest that the annexation may raise the profitability of firm operations in the annexed area, perhaps because of anticipated infrastructure investment or expectations of greater future population growth and lower uncertainty levels, thus leading to increased competition for industrial land and higher prices.

In addition, we investigate how annexation's land-price effects vary with the characteristics of the central city, including GDP, the number of industrial enterprises, population size, and population density in the initial year (2010) of our sample period. The results show that the estimated effects of the annexation exhibit significant heterogeneity along all four dimensions.

We motivate our empirical inquiry by a model of firm investment under uncertainty, adapting the framework of Brueckner and Picard (2015). In the model, a firm chooses to make an irreversible investment in one of two counties, a and b, while also choosing when to invest, in period 1 or 2. The initial returns from the investment, which differ between the counties, are observable, but the second period returns are stochastic, with unfavorable realizations capable of reversing the initial ranking of the counties. As a result, the firm may delay its investment until period 2 in order to observe the realization of these random effects, allowing it to choose the best location going forward. The choice between investing right away or waiting to invest involves a comparison of the lost return due to waiting to the option value of waiting.

The central city's decision to annex a nearby county affects the firm's choices in two ways. First, annexation is likely to raise the initial return in the annexed county, making the firm more likely to invest there if it chooses not to wait. But annexation may also reduce the uncertainty in the annexed county's second-period return, which reduces the option value of waiting and makes the firm more likely to invest immediately, in which case the annexed county will be chosen because of the increase in the period-1 return it offers. The increase in the annexed county's initial return also reinforces this incentive to invest immediately. Thus, annexation leads to immediate investment in the county that is made more attractive by being annexed. This investment choice, which is made by a host of different firms, will put upward pressure on industrial land values in the annexed county, leading to the predicted price effects.

This study is closely related to an extensive literature on urban growth or sprawl. The existing literature has investigated four types of determining factors of urban expansion. The first and largest category is economic factors motivated by the standard model of urban spatial structure (Brueckner, 1987; Fujita, 1989), including market forces such as growing population, rising income, and reductions in the cost of commuting. The effects of these forces are amplified by market failures that involve failure to account for the amenity value of open space and the social costs of freeway congestion (Brueckner and Fansler, 1983; Brueckner, 2000; Irwin and Bockstael, 2004; McGrath, 2005; Song and Zenou, 2006; Anas and Rhee, 2006; Baum-Snow, 2007; Brueckner, 2007; Anas and Pines, 2008; Deng et al., 2008; Paulsen, 2012; Coisnon et al., 2014). The second type of determining factor is local geography, including terrain ruggedness, ground water availability, and the shape of the urban area (Burchfield et al., 2006; Harari, 2020). The third type is political-economy factors, including jurisdictional fragmentation (Mills et al., 2006; Ehrlich et al., 2018) and growth incentives felt by local politicians (Lichtenberg and Ding, 2009; Solé-Ollé and Viladecans-Marsal, 2013; Wang et al., 2020). Finally, the fourth category is government policies and regulations, with urban growth boundaries and other land use regulations drawing the most scholarly attention (Bento et al., 2006; Cunningham, 2007; Anas and Rhee, 2007; Brueckner and Sridhar, 2012; Dempsey and Plantinga, 2013). With a focus on urban expansion directed by governments, our paper belongs to the last category. Unlike existing studies that examine almost exclusively policies to correct externalities and curb urban sprawl, we investigate a government practice that facilitates urban expansion by coordinating expectations and behavior. Thus our paper provides a unique perspective on the role of governments in the process of urban spatial expansion.

Our paper also contributes to a growing literature on jurisdiction adjustments through annexation or amalgamation. Earlier studies, focusing mainly on developed economies, investigate what factors determine jurisdiction adjustments or how these adjustments affect regional economic outcomes. Using census tract level data from areas surrounding 29 large U.S. cities, Austin (1999) finds evidence that annexation is used to offset the political effects of the changed income and racial composition due to population migration. Motivated by the fact that local voters' collective decisions on annexation are a key driver of urban spatial structure in the U.S., Wu and Chen (2015) propose a model to show that cities tend to spread out more and consist of more municipalities in regions with lower agricultural land rents, lower construction costs, and lower rate and uncertainty of income growth. Studying state-imposed administrative adjustments in Sweden, Hanes et al. (2012) find that income differences and size differences of the municipalities affect their willingness to amalgamate. Economies of scale in the provision of public services provide the major rationale for municipal consolidation, which has been discussed in a number of previous studies (Tyrefors Hinnerich, 2009; Reingewertz, 2012; Allers and Geertsema, 2016; Blesse and Baskaran, 2016; Hirota and Yunoue, 2017). Using a series of reforms in Israel, for example, Reingewertz (2012) shows that amalgamations decrease municipal expenditure but have no impact on the level of public services, suggesting the existence of economies of scale. In the context of China, Tang and Hewings (2017) find a growth-promoting effect of "city-county mergers"; Liu et al. (2019) document that annexed counties experience growth of nighttime light intensity, more entry and less exit of manufacturing enterprises, and an increase in manufacturing employment; Han and Wu (2024) similarly find that annexed counties witness faster economic growth, increased specialization in industries with comparative advantage, increased entry of new firms, and increased exit of less profitable firms.[4] However, Deng et al. (2022) show that city-county mergers lead to a loss of per capita GDP in nearby rural areas. As a contribution to this strand of literature, our paper links annexation with parcel-level land prices, which

[4]There is also a small literature in Chinese–by both economists and geographers–that explored the various effects of this practice of annexation on the expanded central cities. See, for example, Tang and Wang (2015), Shao et al. (2018), Zhang et al. (2018), Zhuang et al. (2020), Jin et al. (2021), and Zhang et al. (2022). We learned a great deal of background information from this literature.

capture both the contemporaneous and future effects of annexation on the economy of annexed regions, in the context of a developing country with rapid urban expansion.

In addition, our study contributes to a growing literature on urban land markets in China. This strand of literature investigates a wide variety of topics such as evidence of corruption in the land market (Cai et al., 2013; Chen and Kung, 2019; Li, 2019), the land-market impacts of floor-area-ratio restrictions (Brueckner et al., 2017; Cai et al., 2017), the effects of land quotas (Fu et al., 2021; Qin et al., 2016) and reservation land prices (Lin et al., 2020), as well as the industrial land market and its effects on local development (He et al., 2022; Tian et al., 2022, 2023). We contribute to this strand of literature by quantifying the effect of a different policy practice, government-directed urban growth, on land markets while exploring the channel behind the effect.

The paper is organized as follows. Section 2 discusses the institutional background. Section 3 presents a simple model to motivate empirical analysis. Section 4 introduces the data and reports some descriptive evidence on the impacts of the annexation. Section 5 presents the empirical framework. Sections 6-8 report the empirical results. Finally, we conclude in Section 9.

2 Background: directed urban growth in China

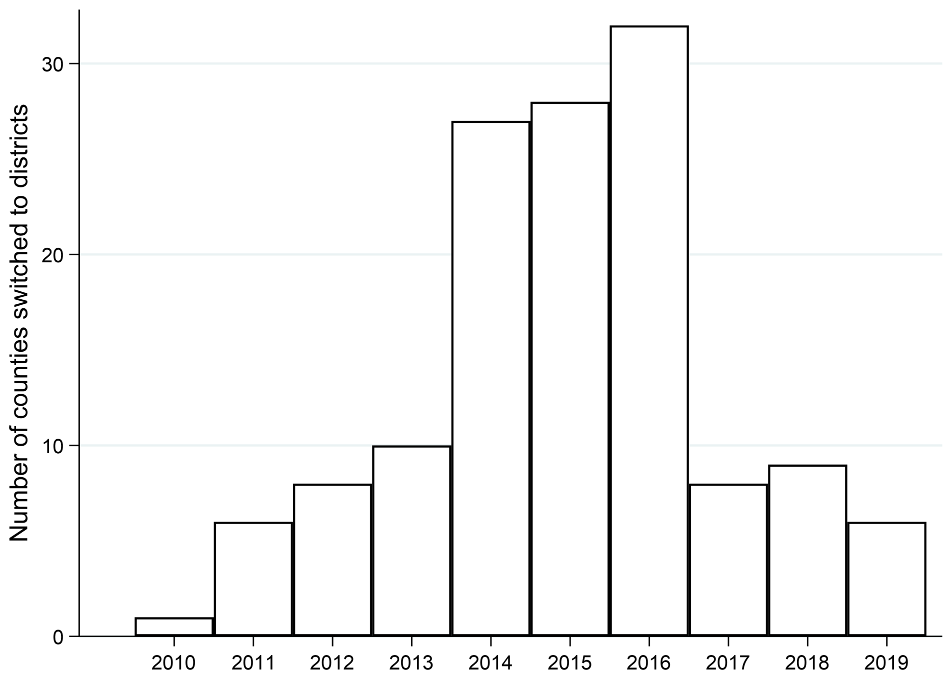
Mainland China has five levels of government: national, provincial (provinces, autonomous regions, and direct-control municipalities), prefectural, counties/districts, and townships. The average province has 11 prefectures, and a typical prefecture is divided into two parts: a central city comprised of one or a few municipal districts, and a peripheral region comprised of several surrounding counties. With the rapid population and economic growth in central cities during the past few decades, a large share of prefectures have expanded their central urban cores by incorporating one or several surrounding counties into the central city. In 2019, the last year of our sample, China consisted of 333 prefectures with 965 urban districts and 1,881 counties. The average prefecture consists of 2.9 urban districts, surrounded by 5.65 rural counties.

Counties and municipal districts in a prefecture play different roles in China's administrative system, although both are classified as county-level divisions. The county government has more autonomy and weaker connections with the prefecture government than the government of municipal districts. Specifically, the prefecture government has direct jurisdiction over municipal districts, and governments of these districts can be seen as agencies of the prefecture government. For example, governments of municipal districts take little responsibility for urban planning, infrastructure construction, and land management, which are instead performed by the prefecture government. In contrast, county governments are granted the power to independently perform these functions, albeit still under the guidance of the prefecture government, and the prefecture government rarely intervenes in the governance of counties. The closer connection between municipal districts and their prefecture government is also reflected in their stronger financial relationship. Compared with counties, districts contribute a larger fraction of their revenues to and also receive more public investment from their prefecture government.

China's central government assigns municipal districts and counties different tasks in pursuing local economic growth. As the core area of a prefecture, both economically and politically, municipal districts prioritize developing secondary and tertiary industries instead of the agricultural sector. In the peripheral counties, however, the primary sector (agriculture, fishing, forestry, etc.) still accounts for a large share of the local economy and is the focus of county governments. In line with such different roles, land uses in counties and districts are regulated differently. Specifically, the central government aims to protect farmland and therefore sets quotas on the amount of land that may be developed, often giving districts higher land quotas to meet their development goals. Once a county is incorporated into the central city, the city will likely obtain a higher land quota for non-agricultural use and thus be able to increase the supply of land to local markets.

Government-directed urban growth has been the main path of urbanization in China during the past two decades. To incorporate a county into the central city of the prefecture, the prefecture government needs to first obtain the county government's agreement and submit a plan to the provincial government for approval. The provincial government then passes the approved plan to the State Council for ratification. The State Council will approve the plan only after due investigation and deliberation. In the early 2000s, China initiated the first wave of administrative reorganization to expand the central cities of many prefectures by facilitating annexation of counties, which became municipal dis-

Figure 1: Annual number of counties annexed into central cities



Notes: These numbers are calculated using data from the Ministry of Civil Affairs.

tricts.[5] Urban land markets had not been fully established at that time, and, in many cases, urban land was allocated administratively by local governments rather than by land markets. In addition, local governments were not required to make land-transaction information public until 2007, even if land parcels were transacted in the market. Both the underdevelopment of land markets and the lack of transaction data make it hard to examine the impacts of the first round of annexations on urban land markets.

The central government revived the practice of expanding the physical sizes of prefecture-level cities in the past decade, particularly after 2014, when China initiated a nationwide program to promote *New Urbanization*.[6] Figure 1 illustrates the yearly number of counties in our sample period, from 2010 to 2019, that were converted to municipal districts and incorporated into central cities. By 2019, the second round of this jurisdictional reorganization had converted 135 counties into municipal districts, among which 97 counties are in our analysis sample.[7] As depicted in Figure 2, the counties/districts in the sample

[5]Turning counties into districts (*che xian she qu* in Chinese) also occurred earlier in China, but only occasionally as isolated cases, not on a large scale.

[6]See http://www.gov.cn/gongbao/content/2014/content_2644805.htm for the *National New Urbanization Plan (2014-2020)*.

[7]We have to drop some of the treated counties from our analysis sample to make these counties comparable. See below in the data section for details.

are widely distributed throughout the country.

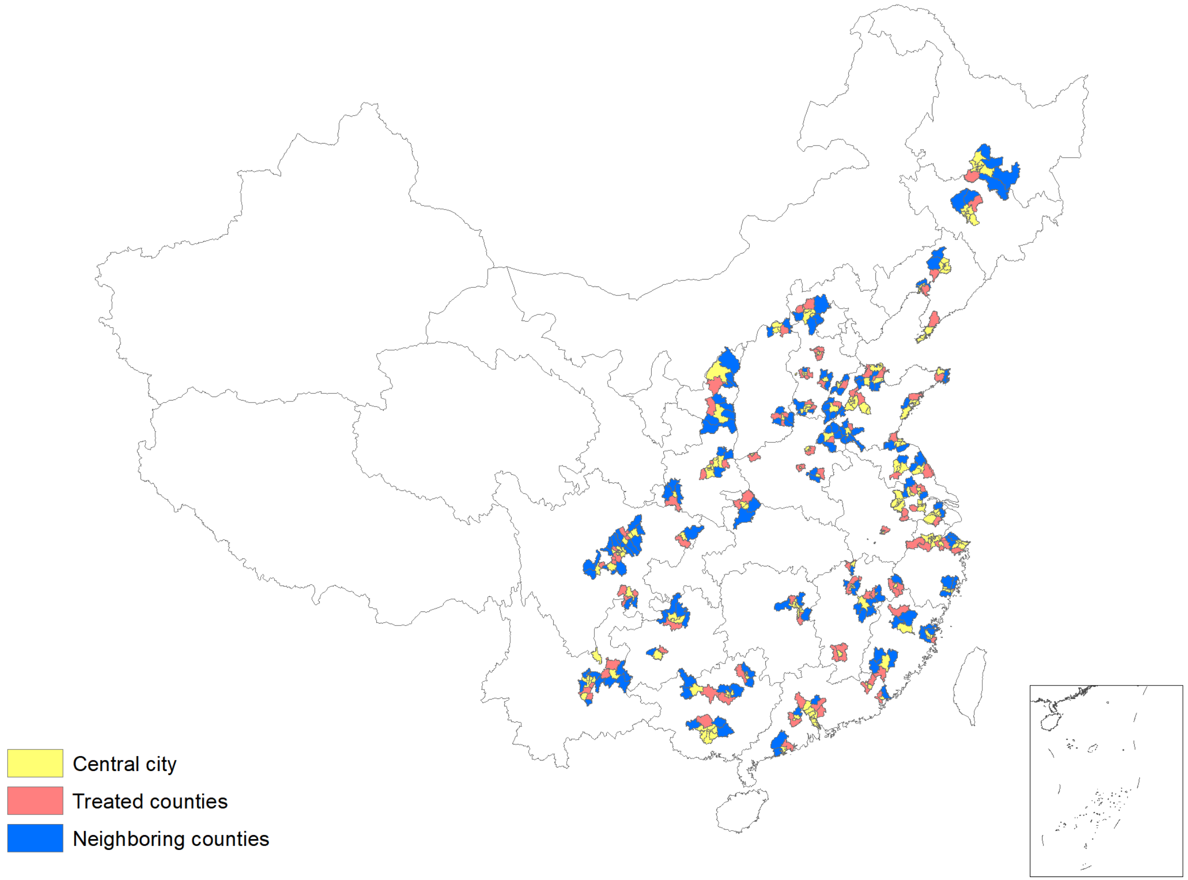
Although we observe a large number of annexed counties, the official guidelines of annexation are not explicitly stated in any public documents. According to some unofficial communications from governments, for a prefecture that plays an important role in the provincial urban system and has good locational conditions and greater development potential, expansion of its central city through annexing counties is more likely to be approved by the central government. Moreover, to apply for an annexation, the prefecture's central city should have a relatively large economy, a high development level, and a high population density. The targeted counties of annexation should have a high urbanization rate, well-developed secondary and tertiary industries, well-developed infrastructure, and well established social security system.[8]

Figure 3 presents two examples of government-directed urban expansion. One is the prefecture-level city *Changzhi* in Shanxi Province, and the other is the prefecture-level city *Shangrao* in Jiangxi Province. In the map, the yellow area represents the scale of the central city in the initial year (2010) of our sample period. The red areas represent the municipal districts that were switched from counties during the sample period (2010–2019). The blue areas are the counties adjacent to the central city that have not been annexed into the central city. Finally, the white areas represent other peripheral counties.

This type of urban expansion through annexation has a few salient features. First, a prefecture that consists of many peripheral counties has several options if the prefecture government intends to expand its central city. For example, the prefecture *Shangrao* was comprised of twelve county-level administrative regions in 2019, including three municipal districts that form the central city and nine peripheral counties. The other prefecture *Changzhi* consisted of four municipal districts and eight counties in 2019. Second, when a county becomes a municipal district, the county as a whole is incorporated into the central city. Although the status of the county is changed, its jurisdictional area remains unchanged. In some special cases, only a part of a county was annexed into the city core

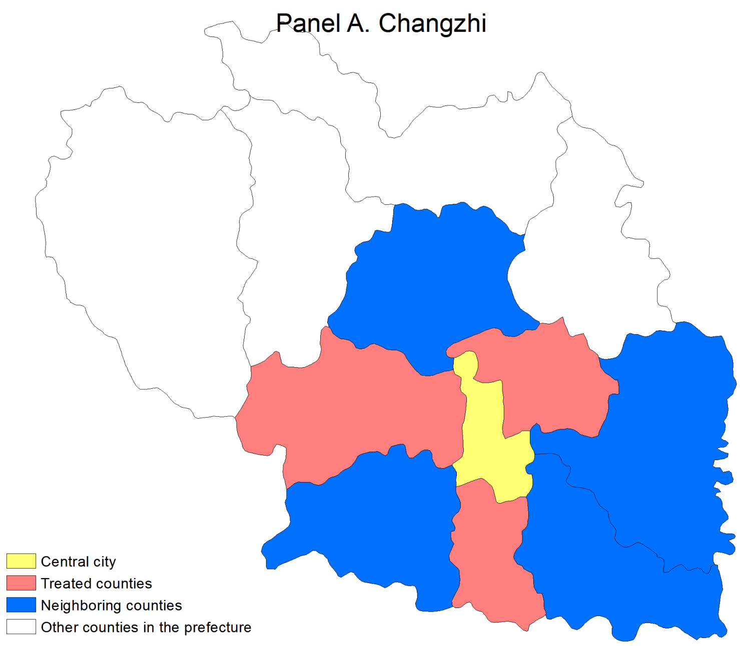
[8]In 2014, China's Ministry of Civil Affairs circulated a draft document that aimed to clarify the conditions under which a county can be turned into a municipal district. For details of the draft, please refer to http://jx.sina.com.cn/news/b/2015-08-06/detail-ifxftkpe2756185-p2.shtml. According to this document, to be turned into a municipal district, a county's urbanization rate should be higher than 50%; the second and tertiary industries should account for 80% of the county's GDP; the public infrastructure and social security system should be well developed and meet a given minimum standard. However, this draft document was never issued as an official one and practices in later years clearly did not fully follow these guidelines.

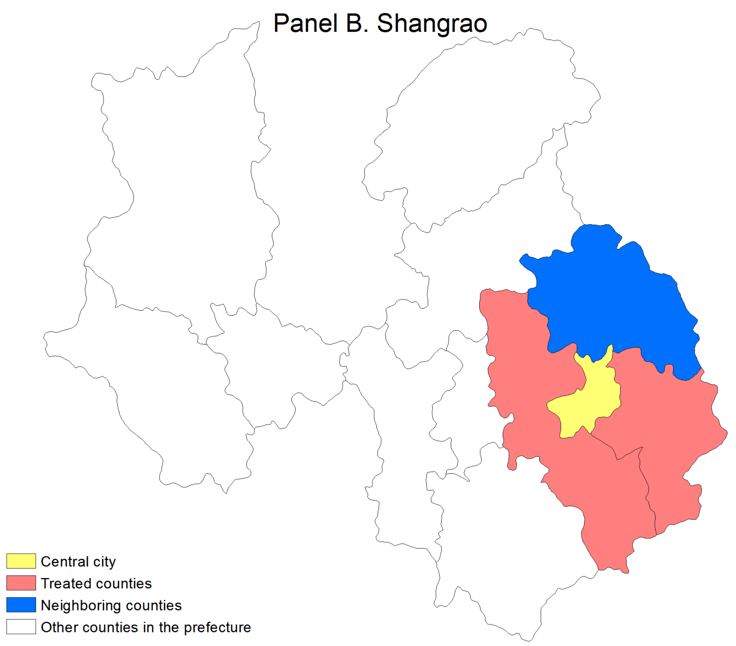
Figure 2: Central cities, annexed counties, and neighboring counties in the sample



Notes: Figure 2 shows city annexations in China during our sample period (2010–2019). Annexations in Xinjiang, Tibet, and the four province-level direct-control municipalities (Beijing, Chongqing, Shanghai, and Tianjin) are not included in the data. The yellow areas represent the central city in 2010, the red areas represent the annexed counties during the sample period (2010–2019), and the blue areas represent the counties that are adjacent to the central city but have not been annexed into the central city.

Figure 3: Examples of the annexation: Changzhi and Shangrao





Notes: Panel A is the map of Changzhi in Shanxi Province and Panel B is the map of Shangrao in Jiangxi Province. The yellow areas represent the central city in 2010, the red areas represent the annexed counties during the sample period (2010–2019), the blue areas represent the counties that are adjacent to the central city but have not been annexed into the central city, and the white areas represent other counties in the prefecture.

and formed a new municipal district or a part of an old municipal district. Such redivisions usually serve special purposes (e.g., to establish a new Economic Development Zone) and since the number of cases is small, we exclude them from the sample in the following analysis. Third, the newly annexed districts always border the original city core while remote counties are not to be incorporated into the central city. As shown in Figure 3, the three new municipal districts (*Shangdang*, *Tunliu*, and *Lucheng*) of *Changzhi* and the two new municipal districts (*Guangfeng* and *Guangxin*) of *Shangrao* are all adjacent to the initial central city. Finally, the initial central cities were compact and small, suggesting that they needed space to grow. For example, the central city of *Shangrao* consisted of only one municipal district (called *Xinzhou*) before 2015. In order to adapt to the rapid urbanization and industrial development in the central city, *Guangfeng* county and the *Shangrao* county were changed to the *Guangfeng* district and the *Guangxin* district in 2015 and 2019, respectively.

Naturally, an annexation does not end with this reassignment of jurisdictions. It is followed by a series of efforts to incorporate the annexed county into the central city. As a new district, the annexed county now has to submit a much larger share of its revenue to the prefecture government in the central city, and the prefecture government will upgrade the infrastructure in the annexed county and expand its public transit system to integrate the new district into the bigger commuting zone. Policies related to school districts, medical care, social security, and other civil services will be adjusted in the central city to assimilate residents in the annexed county as regular urban citizens (Zhuang et al., 2020). There will also be more coordination between the annexed county and those existing urban districts simply by the fact that they are now under the same jurisdiction of the prefecture government (Tang and Wang, 2015; Zhang et al., 2018).

3 Model

3.1 Basic analysis

The analysis explores how the annexation of a county affects firm investment decisions and in turn industrial land prices. The analytical framework is adapted from the option model proposed by Brueckner and Picard (2015). In their model, a decision-maker must choose between two investment locations where initial returns are known but future returns are uncertain, making it potentially optimal to delay investing until the uncertainty is resolved.[9]

The regional economy in the current model has two counties, denoted a and b, which are both adjacent to a central city considering annexation. The model also has two time periods, denoted 1 and 2.[10] A firm must decide in which of the two counties to make a single, irreversible investment and whether the investment should be made in period 1 or 2. The investment requires a one-time outlay of c on physical capital, which is combined with one unit of land to produce output. For the moment, we ignore the firm's payment for land, which is to be determined by the firm's pre-rent profit.

The initial (period-1) return from the investment in county b equals θ, while the initial return in county a equals $\theta + \delta$ where $\theta > 0$ but δ could be either positive or negative, indicating that the period-1 return can be higher or lower in county a than in county b. However, $\theta + \delta > 0$ holds, so that county-a return is positive. The future is uncertain, with returns in period 2 equal to $(\theta + \delta)\epsilon_a$ in county a and $\theta\epsilon_b$ in county b, where ϵ_a and ϵ_b are positive random variables. Given this uncertainty, the firm may wish to delay its investment until period 2, at which point the realizations of ϵ_a and ϵ_b are known, and the county with the highest return going forward can be chosen. If the firm instead decides to invest in period 1, however, it will choose county a if $\delta > 0$ and county b otherwise.

The goal of the analysis is to investigate how annexation of county a by the central city affects the firm's investment decision. We assume that annexation raises δ, increasing the firm's return in county a relative to that in county b, a change that could be driven by new infrastructure investment in the annexed county. In addition, we assume that annexation reduces period-2 uncertainty in the annexed county, making the variance of ϵ_a smaller. With county a more closely tied to the fortunes of the central city following annexation, future economic conditions become less uncertain. After further analysis setting up the firm's choice problem, we show that both these changes make the firm more likely to make its investment in county a, the annexed county, in period 1. Therefore, annexation hastens investment and directs it toward the annexed county.

[9]While their model portrays government infrastructure investment under uncertainty rather than the investment decision of a private firm, the setup is easily adapted to this choice. Beyond the option model, which is used here, their paper also includes an alternative "signaling" model of the investment choice.

[10]While period 2 could be viewed as composite of all future periods beyond period 1, as in Brueckner and Picard (2015), assuming instead that it has the same length as period 1 simplifies the treatment of discounting and the resulting notational burden.

Assuming for simplicity that ϵ_a and ϵ_b have the same expected value, equal to μ, the expected net returns from investing in counties a and b in period 1 are, respectively, equal to

$$R_{1a} \;=\; \theta \;+\; \delta \;-\; c \;+\; \rho(\theta+\delta)\mu, \qquad R_{1b} \;=\; \theta \;-\; c \;+\; \rho\theta\mu, \tag{1}$$

where $\rho < 1$ is the discount factor. From (1), it is clear that, if the firm invests in period 1, then it chooses county a (county b) as $\delta > (<) \; 0$. With annexation raising δ, let us assume that, whatever δ's initial sign, its post-annexation value is positive. Thus, if county a has a pre-annexation return disadvantage relative to county b, annexation reverses it, while if it has a pre-annexation return advantage, annexation strengthens it. The upshot is that, if the firm invests in period 1, annexation leads it to choose county a.

However, by waiting to invest and thus observing the realizations of the random variables, the firm can choose the higher of the post-period-1 net returns, which may occur in county b. Accordingly, the expected net return from waiting until period 2 to invest is given by

$$R_2 \;=\; \rho \; Emax\{(\theta+\delta)\epsilon_a - c, \; \theta\epsilon_b - c\}. \tag{2}$$

Note that the period-1 return is absent.

With annexation implying that investment in period 1 (if it happens) occurs in county a, waiting to invest is not optimal when $R_{1a} > R_2$, or when

$$\theta \;+\; \delta \;-\; c \;+\; \rho(\theta+\delta)\mu \;>\; \rho\, E\, max\{(\theta+\delta)\epsilon_a - c, \; \theta\epsilon_b - c\}. \tag{3}$$

Rearranging (3) after extracting c from the expected value, the condition becomes

$$\theta \;+\; \delta \;-\; (1-\rho)c \;>\; \rho\, E\, max\{(\theta+\delta)\epsilon_a, \; \theta\epsilon_b\} \;-\; \rho(\theta+\delta)\mu. \tag{4}$$

The RHS of (4) gives the option value of waiting to invest. This value equals the expected discounted period-2 net return from putting the investment in the best county (the first term), measured relative to the expected discounted period-2 net return from investing in county a in period 1, given by $\rho(\theta+\delta)\mu$. Since the LHS of (4) represents the loss of net return associated with waiting to invest, satisfaction of (4) indicates that this loss exceeds the option value of waiting, so that waiting is not optimal.[11]

Note that the option value in (4) differs from that in a standard option framework because it captures the firm's ability to choose between *two* investment locations once future conditions become clear. In the usual option model, by contrast, waiting gives the investor a choice between investing or not investing once the future is revealed. Here, the choice is between two alternate investment locations under the assumption that investing somewhere is always optimal.[12]

To rewrite the RHS of (4) in a more usable form, observe that the first term inside the max expression in (4) is optimal (so that county a receives the investment in period 2) when $\epsilon_a > g\epsilon_b$, where $g = \theta/(\theta+\delta)$ captures the relative loss from investing in county b. Conversely, county b receives the investment when $\epsilon_a < g\epsilon_b$.

Let $t(\epsilon_a, \epsilon_b)$ denote the joint density of ϵ_a and ϵ_b, and suppose that both random variables have support $[\underline{\epsilon}, \overline{\epsilon}]$, with $\overline{\epsilon} > \underline{\epsilon} > 0$. Then

$$\rho\, E \max\{(\theta+\delta)\epsilon_a,\ \theta\epsilon_b\} \;=\; \rho \int_{\epsilon_b=\underline{\epsilon}}^{\overline{\epsilon}} \left[\int_{\epsilon_a=g\epsilon_b}^{\overline{\epsilon}} (\theta+\delta)\epsilon_a t(\epsilon_a,\epsilon_b) d\epsilon_a \;+\; \int_{\epsilon_a=\underline{\epsilon}}^{g\epsilon_b} \theta\epsilon_b t(\epsilon_a,\epsilon_b) d\epsilon_a \right] d\epsilon_b. \tag{5}$$

Note that $\epsilon_a > g\epsilon_b$ holds over the range of integration of the first integral inside the brackets in (4), with $\epsilon_a < g\epsilon_b$ holding over the range of the second integral.

With further manipulation, the condition (4) for the non-optimality of waiting reduces to[13]

$$\theta \;+\; \delta \;-\; (1-\rho)c \;>\; \rho(\theta+\delta) \int_{\epsilon_b=\underline{\epsilon}}^{\overline{\epsilon}} \int_{\epsilon_a=\underline{\epsilon}}^{g\epsilon_b} (g\epsilon_b - \epsilon_a) t(\epsilon_a,\epsilon_b) d\epsilon_a d\epsilon_b. \tag{6}$$

[11]The period-1 return of $\theta+\delta$ is lost via waiting. To understand the $(1-\rho)c$ term in (4), note that since ρ is the factor for discounting period 2 income back to period 1, it embodies a discount rate r satisfying $\rho = 1/(1+r)$, so that $(1-\rho)c = rc/(1+r)$. This expression equals the period-1 present value of the interest earned in period 2 on a bank deposit of c made in period 1 as an alternative to making the investment, which is gained when the investment occurs in period 2. Subtracting this gain from the $\theta+\delta$ loss due to waiting, the LHS of (4) equals the (net) loss from waiting to invest.

[12]To ensure that the option of not investing at all is unattractive, a sufficiently low value of c is assumed.

[13]Observe that the second term on the RHS of (4) can be written as

$$\rho(\theta+\delta)\mu \;=\; \rho(\theta+\delta) \int_{\epsilon_b=\underline{\epsilon}}^{\overline{\epsilon}} \int_{\epsilon_a=\underline{\epsilon}}^{\overline{\epsilon}} \epsilon_a t(\epsilon_a,\epsilon_b) d\epsilon_a d\epsilon_b.$$

Subtracting this expression from (5), RHS of (4) can then be rewritten as

$$\rho \int_{\epsilon_b=\underline{\epsilon}}^{\overline{\epsilon}} \left[\int_{\epsilon_a=\underline{\epsilon}}^{g\epsilon_b} -(\theta+\delta)\epsilon_a t(\epsilon_a,\epsilon_b) d\epsilon_a \;+\; \int_{\epsilon_a=\underline{\epsilon}}^{g\epsilon_b} \theta\epsilon_b t(\epsilon_a,\epsilon_b) d\epsilon_a \right] d\epsilon_b.$$

To simplify this expression, $\theta+\delta$ is factored out (recall $g = \theta/(\theta+\delta)$), and the resulting expression is then substituted in place of the RHS of (4), yielding (6).

Again, this condition says that the loss from waiting to invest exceeds the option value of waiting.

3.2 Full comparative-static effects of annexation

While we have already seen that the higher δ due to annexation makes county a, the annexed county, the preferred location for a period-1 investment by the firm, inspection of (6) yields a number of additional comparative-static predictions about the timing of investment. First, since $\rho < 1$, an increase in c reduces the LHS of (6) and thus favors waiting to invest, reflecting gains from delaying the investment cost. The same conclusion applies to an increase in ρ. However, a higher θ raises both the new LHS of (6) and the new RHS (via a higher g), so that an increase in this parameter, which shifts the returns in both counties, has an ambiguous effect on waiting decision.

More importantly, after dividing (6) by $\theta + \delta$, it can be seen that an increase in δ, the post-annexation return advantage in county a, raises the new LHS and reduces the new RHS (since g falls), changes that make waiting to invest less desirable. The intuition is that a higher δ raises the period-1 return that is lost by waiting. Therefore, the higher δ associated with annexation not only makes county a the best place for a period-1 investment, but it also reduces the attractiveness of waiting. Therefore, the possibility that the firm invests in period 2, possibly doing so in county b, is reduced. The higher δ from annexation thus pulls the firm's investment toward period 1, where it will be made in the annexed county.

As noted above, a second expected effect of annexation would be reduction in uncertainty regarding the business climate in county a, given that the county is now part of an annexing central city. In the context of the model, a reduction in uncertainty in county a would reduce the variance of the random variable ϵ_a that affects the county's period-2 returns, without affecting uncertainty in county b.

It is unfortunately not possible, using (6), to derive analytically the effect of such a reduction in uncertainty. However, the effect can be illustrated in numerical examples. In particular, under the assumption that the random terms ϵ_a and ϵ_b have a bivariate normal distribution, the effect of a decrease in ϵ_a's standard deviation, denoted σ_a, on the option value of waiting (magnitude of the RHS of (6)) can be assessed numerically. Based on a number of different parameterizations of the bivariate normal, results show that the

Table 1: Dependence of option value on county a's standard deviation

σ_a	$\sigma_{a,b}=0.6$	$\sigma_{a,b}=0.4$	$\sigma_{a,b}=0.2$
1.0	0.0536	0.0911	0.1280
0.9	0.0397	0.0731	0.1068
0.8	0.0289	0.0578	0.0879
0.7	0.0211	0.0454	0.0715
0.6	0.0160	0.0359	0.0578
0.5	0.0134	0.0291	0.0470
0.4	0.0128	0.0251	0.0389
0.3	0.0142	0.0234	0.0336
0.2	0.0169	0.0241	0.0309

RHS of (6) decreases in magnitude when σ_a decreases, moving away from equal degrees of uncertainty. With the option value of waiting then falling, the waiting decision becomes less desirable when uncertainty in county a declines, an intuitively sensible result given that, with less future uncertainty in that county, a firm is less likely to regret a decision to invest in period 1.

For the calculations, the common mean of ϵ_a and ϵ_b is set at 3.0, and the standard deviation σ_b of ϵ_b is set at 1.0. With σ_a (the standard deviation of ϵ_a) varying from from 1.0 to 0.2 and the large means of ϵ_a and ϵ_b, the probability of negative values of these random variables is virtually zero, as assumed. Finally, $g = \theta/(\theta + \delta)$ is set at 0.7. Table 1 shows the magnitude of the option value as σ_a falls from 1.0 to 0.2 under several values of the correlation coefficient of ϵ_a and ϵ_b, denoted $\sigma_{a,b}$ (it equals 0.6, 0.4, and 0.2). As can be seen, the option value falls monotonically in each column of Table 1, except at the bottoms of columns 1 and 2, where it increases slightly as σ_a falls. This pattern, where the option value rises slightly with σ_a when the standard deviation is small, appears in some other parameterizations as well. But for all parameterizations, the option value is decreasing in σ_a as it initially falls below σ_b, indicating that a reduction in uncertainty in county a, starting from a position of equality, reduces the option value of waiting.

This effect, along with the annexation's effect on δ, makes a firm more likely to invest immediately (choosing county a) after the county's annexation. Thus, the assumed effects of county a's annexation on the firm's (expected) return in the county (the positive effect on δ) and on the period-2 uncertainty of the county-a return (the negative effect on σ_a) both reduce the option value of waiting, pulling the firm's investment toward period 1, where annexation makes county a the preferred choice.

3.3 Effects on land prices

To draw a link between annexation and land prices, recall that an investing firm must acquire a unit of land in order to make its investment, an assumption that has no effect on the foregoing analysis. As usual, competition among firms will bid up the land price so that the discounted net return less the land cost is reduced to zero. The resulting land price, which captures the firm's willingness-to-pay for land, then equals the relevant net return expression from above. In other words, the (county a) land price paid by a firm investing in period 1 equals $p_{a,1} = (1 + \rho\mu)(\theta + \delta) - c$ after rearranging (1) (recall that μ is the common mean of ϵ_a and ϵ_b). Since $p_{a,1}$ increases with δ, annexation raises a firm's willingness-to-pay (hence its "demand") for land in county a in period 1, when its post-annexation investment is made, which in turn raises the land price. The model then predicts that annexation should immediately (in period 1) raise industrial land prices in the annexed county.

The mechanism by which the land price rises is through entry of new firms. Firms investing in the county prior to annexation would have paid a land price based on the original value of δ, but once δ rises following annexation, profit (the discounted return) net of land cost would become positive. This profit would attract new entrants, and competition among them would bid up the land price until profit is eliminated. Therefore, new-firm entry in county a and the rising price of land go hand in hand. Since each county is likely to face a perfectly elastic supply of firms seeking profit opportunities, the new entrants in county a are likely to come from all over the country. While some firms may be diverted from county b, putting downward pressure on its land price, the resulting enhancement of profit would attract replacement firms from elsewhere until county b's land price rises back its original level (consistent with the absence of beneficial infrastructure investment in the county).

One caveat to these predictions concerns the supply of land. In China, urban land is owned by the state (effectively, by the prefecture government). If the government's goal is to maximize land revenue, then it should provide land to any firm that is able to pay more than the land's agricultural income, in which case the previous predictions hold. On the other hand, if the prefecture government puts a high priority on preserving farmland or is tightly constrained by land conversion quotas (Fu et al., 2021), then industrial land may not be made available, and there may not be a significant increase in firm entry and investment in the annexed county. Even in this case, however, competition among *potential* entrants would still bid up the price of land following annexation.

Since our model's most robust prediction is that annexation raises industrial land prices, we will devote the bulk of our empirical analysis below to this hypothesis. But, using available data, we will also check whether annexations lead to more firm entry and investment.

4 Data and descriptive evidence

4.1 Data

The data used in this study come from three sources. The first is the adjustments of administrative divisions reported by the Ministry of Civil Affairs (MCA) of China. We record all status switches from counties to municipal districts from the official website of the MCA.[14] The key information is the year when an annexation occurred. Based on this information, we construct a dummy variable DUG, which equals 1 if the annexation has occurred. For each case of annexation, we also identify the central city and the counties adjacent to the central city but not annexed into the central city. For the land price and other outcome variables, we collect information not only for the annexed county but also for the central city and other counties adjacent to the central city.

The second data source is the website of *landchina* maintained by the Ministry of Natural Resources (MNR), which has made public a rich vein of land use information at the parcel level in China since 2007.[15] Most importantly for our study, *landchina* releases information on all land lease transactions in China. For every transaction, *landchina* reports an array of land parcel characteristics, including the leasehold length, land grades, whether the parcel is newly converted for urban use or redeveloped urban land, and a two-digit industry code of the buyer. We use transaction price and area to calculate the land price per hectare and adjust it to the 2010 price level using provincial CPI. *Landchina* also reports the mode of land transaction, including auction, transfer by agreement, and government appropriation. Compared with a land auction, transfer by agreement and appropriation by government leave room for local governments to intervene in land

[14] See http://www.mca.gov.cn/article/fw/cxfw/jzz/.

[15] The *landchina* website is https://www.landchina.com.

transactions, so that the resulting prices may deviate from market values. In addition, *Landchina* reports the level of government that approves the transaction, which may be the local government or an upper–level government. The central government had suspended county-to-district switches for several years before 2010, and good quality land transaction data were not available before 2007, so our analysis sample only includes land transactions after 2010.

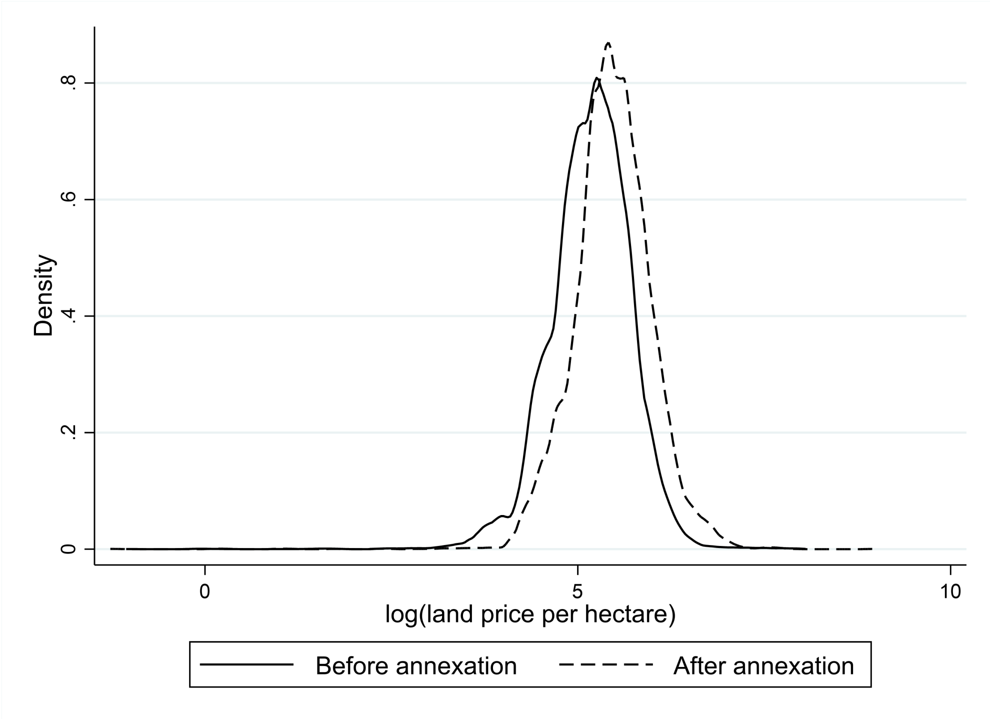
Finally, we rely on statistical yearbooks for regional information such as overall and sectoral GDP, population, population density, fixed-asset investments, and local finance at the county/district and prefecture levels. The yearly number of new firms in counties and municipal districts is calculated using the registration information of enterprises from the State Administration for Market Regulation (SAMR). To measure a county's relative position in the prefecture, we calculate the distance from the county centroid to the prefecture centroid using the prefecture map.

We trim the data in the following ways. First, starting with the land data, we determine each land parcel's location using the reported county ID and only keep parcels located in our sample counties and municipal districts. Second, we keep land transactions from 2010 to 2019. Third, we only keep land parcels used for industrial purposes, including manufacturing, mining, water supply, and storage. Fourth, we drop land transactions with missing land prices or areas. Fifth, to make counties/districts comparable across provinces, we exclude counties from the four province-level direct-control municipalities, including Beijing, Chongqing, Shanghai, and Tianjin. We also exclude counties from Xinjiang and Tibet, which are significantly different from other provinces in geographical conditions, administrative systems, culture, and economic policies. Finally, our data include 97 treated counties that had been switched to municipal districts from 2010–2019. The control group includes 155 counties that are adjacent to the central city but were not annexed into central cities during the sample period (2010–2019). In these treated and control counties, we observe over 56,000 industrial land transactions during the sample period.

4.2 Descriptive evidence

Table 2 reports the descriptive statistics of county-level economic indicators in the initial sample year (2010). Column (1) is for counties in the treatment group and Column (2)

Figure 4: Industrial land prices before and after annexation in annexed counties



Notes: All land prices are adjusted to the 2010 price level using provincial CPIs.

is for counties in the control group. Column (3) presents the differences between these two groups conditional on province fixed effects, and p-values are reported in parentheses. Both the total population and rural population show no difference between treated and control counties. Neither GDP nor the value added in the secondary and tertiary industries shows a gap significant at the conventional level. To measure the relative importance of a county, we use two indicators, the GDP share and the financial-revenue share of a county in its prefecture. Neither one shows a significant difference between treated and control counties, suggesting that the two groups of counties are more or less equally important to their prefectures. Finally, the provision of healthcare facilities, represented by the number of hospital beds per capita, shows no difference between the two groups of counties. In sum, Table 2 shows that in the initial year of our sample period, there were no statistically significant differences between the treated and control counties along a number of important dimensions.

One naturally expects that the more developed counties are more likely to be annexed, and thus may find the lack of significant differences in Table 2 somewhat surprising. It is important to recognize that although counties close to a central city tend to be more

Table 2: Characteristics of counties in 2010

Variable	(1) Treatment group	(2) Control group	(3) Difference
Population (100,000)	57.742	60.626	-4.667
	(28.593)	(34.348)	(0.197)
Rural population (100,000)	48.629	50.755	-3.782
	(24.833)	(30.200)	(0.245)
GDP (million yuan)	189.683	168.538	5.345
	(176.692)	(234.527)	(0.834)
Secondary sector GDP (million yuan)	105.800	91.749	3.878
	(106.171)	(148.099)	(0.809)
Tertiary sector GDP (million yuan)	60.054	54.436	0.364
	(64.918)	(84.908)	(0.969)
Ratio of county to central-city GDP (%)	11.800	10.578	0.275
	(10.429)	(13.705)	(0.853)
Ratio of county to central-city revenue (%)	29.049	26.005	3.787
	(35.647)	(36.584)	(0.404)
Debt to GDP ratio	0.507	0.509	-0.014
	(0.282)	(0.270)	(0.602)
Number of students (100,000)	0.712	0.736	-0.077
	(0.453)	(0.478)	(0.145)
Hospital beds per 10000 people	25.048	25.273	1.154
	(10.737)	(12.782)	(0.422)
Observations	97	155	252

Notes: Column (1) reports the summary statistics of county-level characteristics in 2010 for counties treated by the annexation. Column (2) reports the summary statistics of county-level characteristics in 2010 for counties that are adjacent to the central city but were not annexed by the central city during the sample period (2010–2019). In Columns (1)-(2), standard deviations are in parentheses. Column (3) reports the differences conditional on province fixed effects and p-values are reported in parentheses.

developed than remote counties, those in the former group are not that much different from one another. This is exactly why we decided to use other counties adjacent to the central city as control counties. The results in Table 2 also reflect the fact that the significantly more developed counties may refuse to be annexed. Remember that the policy requires the annexation to be agreed by the annexed county. Since the annexed county will lose a great deal of autonomy, leaders of the most developed counties may not find it attractive to be merged into the central city. This has indeed happened in practice. A widely reported case involves *Changxing* county in Zhejiang Province. In 2013, there was a proposal to annex it into the city of *Huzhou*, which was later blocked by hundreds of county cadres in anticipation of reduced administrative power (Zhang et al., 2018). In any case, this comparability between treated and control counties allows for a simple and transparent empirical strategy to measure the effect of annexation.

Before conducting formal econometric analysis, we visualize the patterns of the key outcome variable in Figure 4. Using the sample of the treated counties, Figure 4 displays the distribution of industrial land prices in treated counties before and after the annexation was implemented. The horizontal axis is the logarithm of industrial land prices, and the vertical axis is the density. The solid line and the dotted line represent the price density of land transacted before and after the annexation, respectively. As shown in Figure 4, the distribution clearly shifted to the right, suggesting that industrial land prices in a treated county increase significantly after the county is annexed into the central city under the direction of upper-level governments.

5 Empirical strategies

We adopt two empirical strategies to explore the impacts of annexation on industrial land prices. First, we conduct an event study using only land transactions in the annexed counties. Specifically, we run the following regression:

$$\log Price_{ict} = \alpha + \beta * DUG_{ict} + \psi * X_{ict} + f_c + \delta_{pt} + \varepsilon_{ict}, \tag{7}$$

where $\log Price_{ict}$ is the log price per hectare of industrial land for parcel i in county/district c in year t. The key explanatory variable, DUG_{ict}, is a dummy equal to 1 if the county/district c where land parcel i is located had been converted into a municipal district and annexed into the central city in year t or earlier. Specifically, if the status of the county/district c is *county* instead of *municipal district* in year t, then the value of DUG_{ict} is 0. The estimated coefficient β represents the effect of the annexation on industrial land prices, identified by comparing land prices before and after annexation.

X_{ict} represents a set of land parcel characteristics that serve as control variables, including transaction mode dummies, land grade, land area, leasehold length, level of the government that approved the land transaction, and distance to the county center. To remove the time trend of land prices within counties, we control for the interaction terms between year dummies and each county's median land price in 2010 (the start year of our sample period), allowing for a flexible land price trend. We cluster the standard errors at the county/district level to account for correlation within counties/districts (Moulton, 1986; Bertrand et al., 2004).

Counties and districts in our sample are widely distributed all over the country, as portrayed in Figure 2, and have a great deal of variation in the level of economic development. Some time-invariant characteristics at the county level, such as the distance to economic centers, the abundance of land and other natural resources, and local industrial infrastructure, could all affect local industrial land markets. For example, the proximity to national or regional economic centers may help a county attract enterprises and thus boost land prices in the county. The abundance of land in a county may affect local land supply and in turn land prices in the county. To remove the effects of these time-invariant factors at the county level, we control for the county fixed effects f_c by including the county indicators in the regression of equation (9) and only focus on within-county variations.

Over our sample period (2010–2019), China experienced various domestic and international shocks. For example, the central government frequently put pressure on provincial governments to regulate land markets within their jurisdictions. Since the Eighteenth National Congress of the CPC in 2012, China has paid more attention to poverty alleviation and economic development in backward rural counties, which may affect the industrial land markets of developed and developing regions in different ways. During our sample period, drastic changes in the international environment, such as the escalating trade conflicts between the U.S. and China, impacted industrial development and consequently industrial land markets in China. Due to the vast territory of China and large variation across regions, the effects of these domestic and international changes on industrial land markets may be region-specific. We thus include the province-year fixed effects, represented by δ_{pt}, in equation (9).

The second empirical strategy is the DID method. The control group includes the counties that adjoin the central city but were not switched to municipal districts during the sample period. As shown in Table 2, the economic characteristics show no statistically significant differences between the treated and control counties, suggesting that using these peripheral counties as the control group is appropriate. We then estimate equation (9) again using the DID strategy with the larger sample. The estimated coefficient β captures the effect of annexation, now identified by comparing the differences between treated and control counties before and after annexation.

In addition to the average effects, we also examine the yearly effects of the annexation using the following flexible specification:

$$\log Price_{ict} = \alpha + \sum_{j=-5}^{-2} \beta_j * before_{icj} + \sum_{j=0}^{4} \beta_j * after_{icj} + \psi * X_{ict} + f_c + \delta_{pt} + \varepsilon_{ict}. \quad (8)$$

Our key explanatory variables are $before_{icj}$ and $after_{icj}$, which are dummies indicating the year of transaction relative to the year when county c was switched to a municipal district. The year before the annexation ($j = -1$) is the reference year. In our analysis below, we will estimate the year-by-year effects using both the event-study strategy and the DID strategy.

6 Empirical results

6.1 Baseline results

6.1.1 Average effects of the annexation

Table 3 reports evidence for the effects of the annexation on industrial land prices in treated counties. Columns (1)–(2) present the results from the event study. By controlling for the land price trend, the county fixed effect, and the province-year fixed effect, Column (1) shows that incorporating an adjacent county into the central city raises industrial land prices in the treated county by 7.16 percent. Column (2) further controls for the effects of

Table 3: Baseline results

DV: Log industrial land price	(1)	(2)	(3)	(4)
	Event study		DID	
DUG	0.0716**	0.0699***	0.0842***	0.0696***
	(0.0311)	(0.0237)	(0.0298)	(0.0267)
Parcel-level controls	No	Yes	No	Yes
Price_trend	Yes	Yes	Yes	Yes
County_FE	Yes	Yes	Yes	Yes
Province_Year_FE	Yes	Yes	Yes	Yes
Observations	23956	23956	56620	56620
Adjusted R^2	0.667	0.711	0.690	0.730

Notes: Columns (1) and (2) report the results of the event study using the sample of treated counties incorporated into central cities. Columns (3) and (4) report the results of the DID estimation by defining the control group as treated counties' neighboring counties that are adjacent to the central city. Parcel-level controls include transaction mode dummies, land grade, land area, leasehold length, level of the government that approved the land transaction, and distance to the county center. Price trend is controlled by the interaction terms between year dummies and the county's median land price in 2010. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

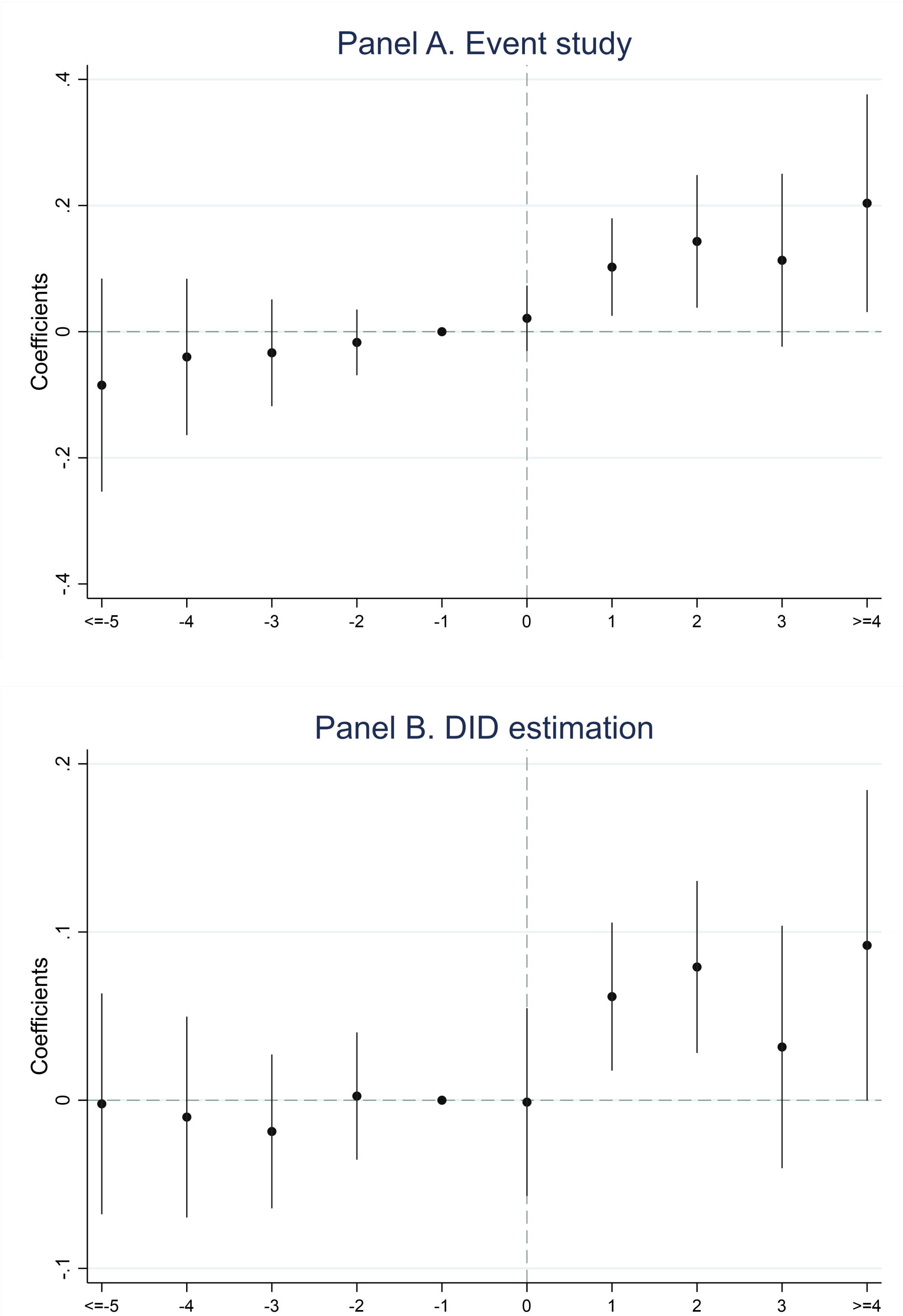
land-parcel characteristics, including land area, leasehold length, land grade, transaction modes, whether the parcel is newly converted for urban use, level of the government approving the land transaction, and distance from the land parcel to the county center. It shows that annexation significantly increases industrial land prices by 6.99 percent.

Columns (3)–(4) report the results from the DID estimation with a control group, using land transactions from the counties that are adjacent to both the central city and a treated county but were not incorporated into the central city. As in Column (1), if we only control for the land-price trend, the county fixed effect, and the province-year fixed effect, annexation significantly increases industrial land prices by 8.42 percent (Column (3)). If we further control for land-parcel characteristics, the estimated coefficient shows that annexation significantly increases industrial land prices by 6.96 percent (Column (4)), which is almost identical to the effect estimated in the event study (6.99 percent). Overall, we find consistent evidence across different specifications that annexation raises industrial land prices in the treated counties.

6.1.2 Dynamic effects of annexation

To investigate the year-by-year effects of the annexation, we estimate equation (10) with the same set of controls as in columns (2) and (4) of Table 3. Figure 5 portrays the coefficients of year-distance indicators using one year prior to annexation as the reference year.

Figure 5: Dynamic effects of annexation



Notes: This figure plots the coefficients of year distance indicators estimated from equation (10), using one year prior to annexation as the reference year. Control variables included are the same as those in columns (2) and (4) of Table 3 (see notes under the table). The dots represent the values of estimated coefficients, and the vertical lines represent the 95 percent confidence intervals. Panel A plots the event study coefficients estimated using observations from the treated counties only, and Panel B plots the DID coefficients estimated using observations from both the treated and control counties.

The dots represent the values of estimated coefficients, and the vertical lines represent the 95 percent confidence intervals. Panel A plots the coefficients of year-distance indicators estimated from the event study, which focuses only on treated counties. For $j < -1$, the coefficients of year-distance indicators estimated from (10) are not significantly different from zero, although there seems to be a slightly increasing trend of industrial land prices before the annexation was implemented. In contrast, for $j > 0$, the coefficients of the year-distance indicators become significantly positive, suggesting that annexation increases industrial land prices. Panel B plots the coefficients of year-distance indicators estimated from the DID specification, where both treated and control counties are included. The parallel trend assumption seems to hold since the differences between treated and control counties are statistically insignificant and almost exactly zero during the pre-treatment years. Similar to Panel A, Panel B shows that the estimated coefficients of the year-distance indicators become significantly positive after annexation. Therefore, the year-by-year effects estimated from both the event study and the DID regression confirm the baseline results that annexation significantly increased industrial land prices in the treated counties.

6.1.3 Robustness checks

The treatments in our analysis sample occurred in different years. It is by now well-known that the standard two-way fixed effect estimator as in equation (9) is a weighted average of all possible two-county-two-period DID estimators in the sample. Surprisingly, an early-treated county may get negative weights if it serves as a "control" for many later-treated counties (Goodman-Bacon, 2021). Following the diagnostic approach proposed by de Chaisemartin and D'Haultfœuille (2020), we find little if any negative weights in our baseline estimation, suggesting that the varied timing of treatment is unlikely to have seriously biased our baseline estimates.

Despite the favorable diagnosis, we tried five alternative heterogeneity-robust DID estimators as robustness checks. The primary issue with the baseline two-way fixed-effect approach is the "forbidden comparisons" between units treated later and those already treated. To avoid such comparisons, the alternative estimators employ different strategies. Four of the five alternative estimators pair treated counties in each cohort with a group of "clean" controls and then aggregate cohort-specific DID estimates into overall effects. Specifically, we divide treated counties into different cohorts based on the treatment year, using never-treated adjacent counties as the control group for each cohort. The first method follows the approach used by Cengiz et al. (2019), stacking different cohorts to estimate DID coefficients.[16] The other three approaches—proposed by Sun and Abraham (2021), Callaway and Sant'Anna (2021), and de Chaisemartin and D'Haultfœuille (2024)—aggregate cohort-specific DID estimates using different weighting schemes. We also tried a fifth alternative estimator, using the imputation method by Borusyak et al. (2024). Here we first fit a two-way fixed-effect model of land price as specified in equation (10) using untreated counties, then use this model to predict the counterfactual land price for treated counties. Subtracting the counterfactual land price from the actual land price of treated counties yields an estimate of the treatment effect. Results from these alternative methods, shown in Figure A.1 in the Appendix, are broadly consistent with the baseline results, indicating parallel pre-trends and a positive treatment effect. Therefore, the effects on industrial land prices are unlikely to be driven by bias from staggered treatment timing.

6.2 Further analysis

6.2.1 Controlling for county characteristics

One relevant concern is that some unobserved initial county characteristics may affect both the initiation of the annexation and industrial land prices in the county, leading to a potential omitted-variable bias. For example, if the manufacturing industry was well developed in a county adjacent to the central city, then industrial land prices in the county would likely be higher and the county would be more likely to be annexed into the central city. To address this concern, we further include some initial county characteristics in (9), including population, GDP, industrial structure (share of the secondary sector in GDP), and urbanization rate (share of the non-agricultural population in total population). Given that the impacts of these characteristics may be different from year to year, we control for the effect of each county characteristic in 2010 (the start year of our sample period) interacted with year dummies. Table 4 reports the results. Columns (1) and (2)

[16] Gardner et al. (2024) point out that this approach estimates a weighted average of cohort-specific average treatment effects, with weights determined by relative cohort size and the variance of treatment status within each cohort.

Table 4: Robustness checks: initial characteristics of counties

DV: Log industrial land price	(1)	(2)
DUG	0.0839***	0.0760***
	(0.0204)	(0.0240)
County characteristics in 2010 × Year dummies	Yes	Yes
Parcel-level controls	Yes	Yes
Price_trend	Yes	Yes
County_FE	Yes	Yes
Province_Year_FE	Yes	Yes
Observations	23955	56618
Adjusted R^2	0.715	0.732

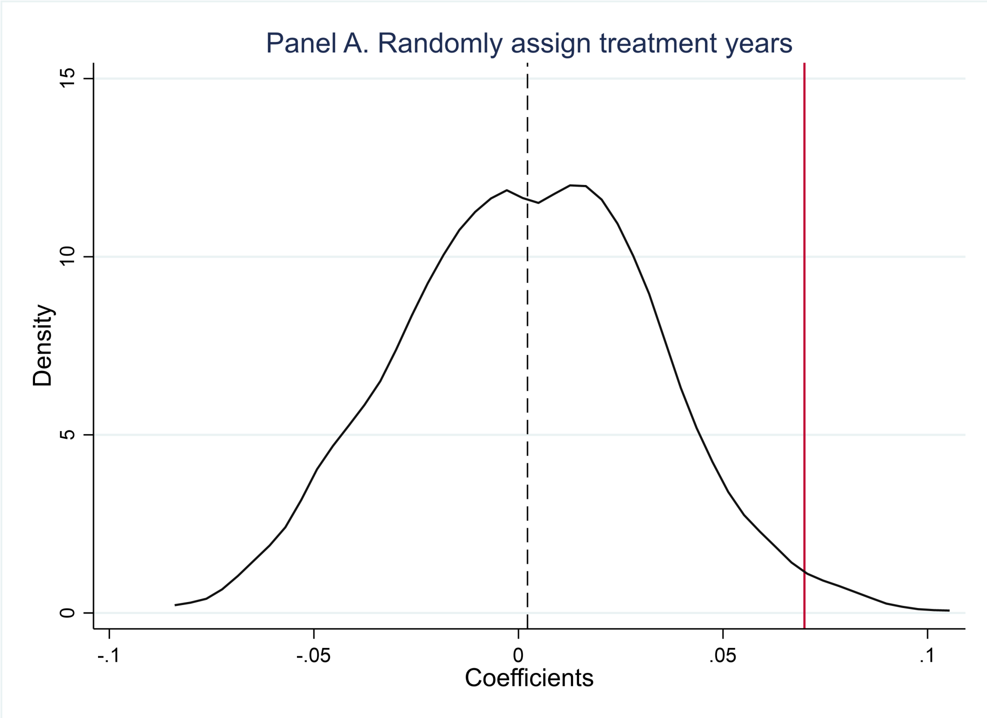
Notes: This table reports the results after controlling the county-level characteristics in 2010 times year dummies. Column (1) presents the results of the event study using the sample of treated counties incorporated into central cities. Column (2) reports the result of the DID estimation by defining the control group as treated counties' neighboring counties that are adjacent to the central city. Parcel-level controls include transaction mode dummies, land grade, land area, leasehold length, level of the government that approved the land transaction, and distance to the county center. Price trend is controlled by the interaction terms between year dummies and the county's median land price in 2010. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

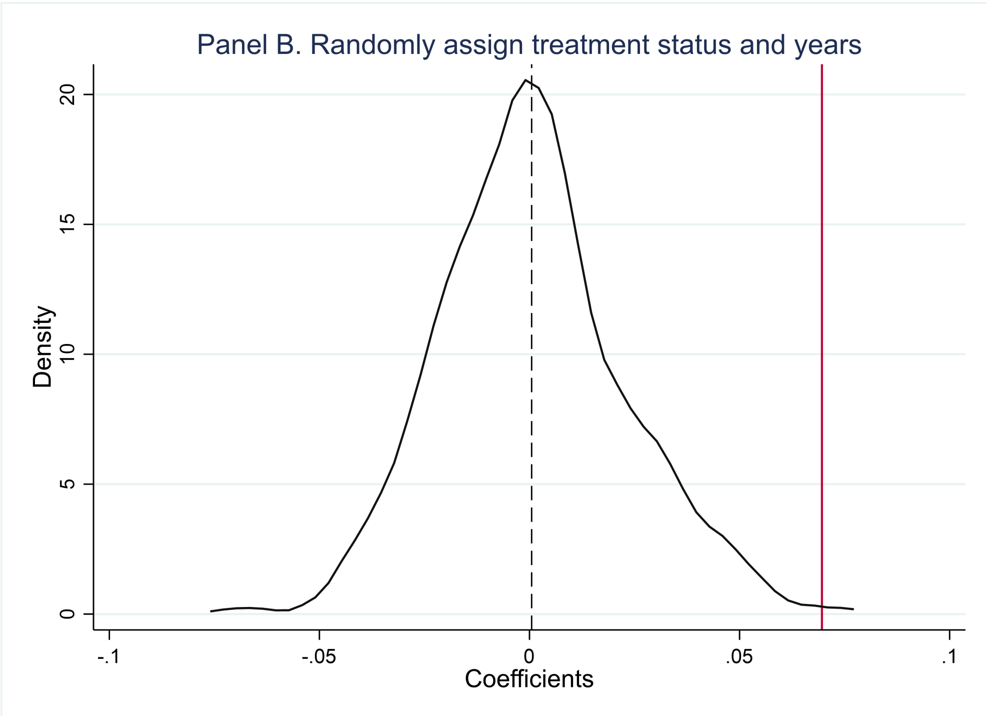
report the coefficients estimated from the event study and the DID method, respectively. The coefficients of interest are similar to those reported in Table 3 in terms of both their magnitudes and significance levels. Therefore, our result that annexation raises industrial land prices is robust to including more county-level controls.

6.2.2 Impacts on neighboring regions

Another concern is whether the land price increase in the treated counties comes at the expense of land price declines in neighboring regions. To check for this possibility, we examine the impact of annexation on industrial land prices in central cities and neighboring counties in the control group. Columns (1) and (2) in Table 5 report the estimated coefficients of the DUG dummy using land transactions in central cities and neighboring counties, respectively. Both coefficients of the DUG dummy are small in magnitude and neither is significantly different from zero, implying that annexation had no significant impacts on industrial land prices in central cities and neighboring counties of the treated counties. In other words, the positive effect of the annexation on the treated county is unlikely a result of redistribution from other regions in the prefecture, as suggested by the theoretical model.

Figure 6: Distribution of estimated coefficients in the placebo tests





Notes: Each distribution is based on coefficients from 500 estimations in the placebo test. Panel A plots the distribution of coefficients when we randomly assign the annexation year for treated counties. Panel B plots the distribution of coefficients when we randomly assign both the treatment status and the treatment year among the sample of both treated and control counties. The red vertical lines represent the benchmark estimates reported in Columns (2) and (4) of Table 3.

Table 5: Effects of annexation in the central city and neighboring counties

DV: Log industrial land price	(1) Central city	(2) Neighboring counties
DUG	0.0093	-0.0183
	(0.0419)	(0.0325)
Parcel-level controls	Yes	Yes
Price_trend	Yes	Yes
County_FE	Yes	Yes
Province_Year_FE	Yes	Yes
Observations	34999	32664
Adjusted R^2	0.403	0.746

Notes: This table reports the effects of annexation on industrial land prices in central cities and neighboring counties that are adjacent to the central city but have not been annexed by the central city during the sample period (2010–2019). Parcel-level controls include transaction mode dummies, land grade, land area, leasehold length, level of the government that approved the land transaction, and distance to the county center. Price trend is controlled by the interaction terms between year dummies and the central city's or county's median land price in 2010. Standard errors are clustered at the central city level in Column (1) and at the county level in Column (2). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.2.3 Placebo tests

One might be concerned that the estimated effects of annexation on land prices may result from some omitted variables. To explore this possibility, we conducted two placebo tests by randomly assigning the date of annexation. First, we randomly assign the year of annexation for the sample of counties annexed into the central city during our analysis period (the sample used in Column (2) of Table 3). Second, we randomly assign both the annexation treatment and the year of the treatment for the sample of counties used in Column (4) of Table 3, including both the treated and control counties. Specifically, for this second test, we randomly select 97 counties from the whole sample of 252 counties as the treatment group and then randomly assign a treatment year for each selected county in this artificial treatment group. We estimate the baseline equation (9) using both of these randomly constructed samples.

Figure 6 reports the results of these placebo tests from 500 repetitions. Panel A plots the distribution of the coefficients of the DUG dummy if we randomly assign the year of annexation for treated counties. The mean of these estimates (0.0022) is almost 0 with a standard deviation of 0.0304, suggesting that the randomly timed annexation does not affect industrial land prices. If we randomly assign both annexation and the year of the reform, the estimates still cluster around 0, as plotted in Panel B, with a mean of 0.0005 and a standard deviation of 0.0217. Moreover, in both panels, the vertical lines representing the benchmark estimates from the event study (0.0699) and the DID estimation (0.0696) are located at the far right of the distribution and are significantly different from zero. Therefore, the results of these placebo tests suggest that our estimated effects of annexation are unlikely to be driven by some omitted factors.

6.2.4 Heterogeneity by characteristics of central cities

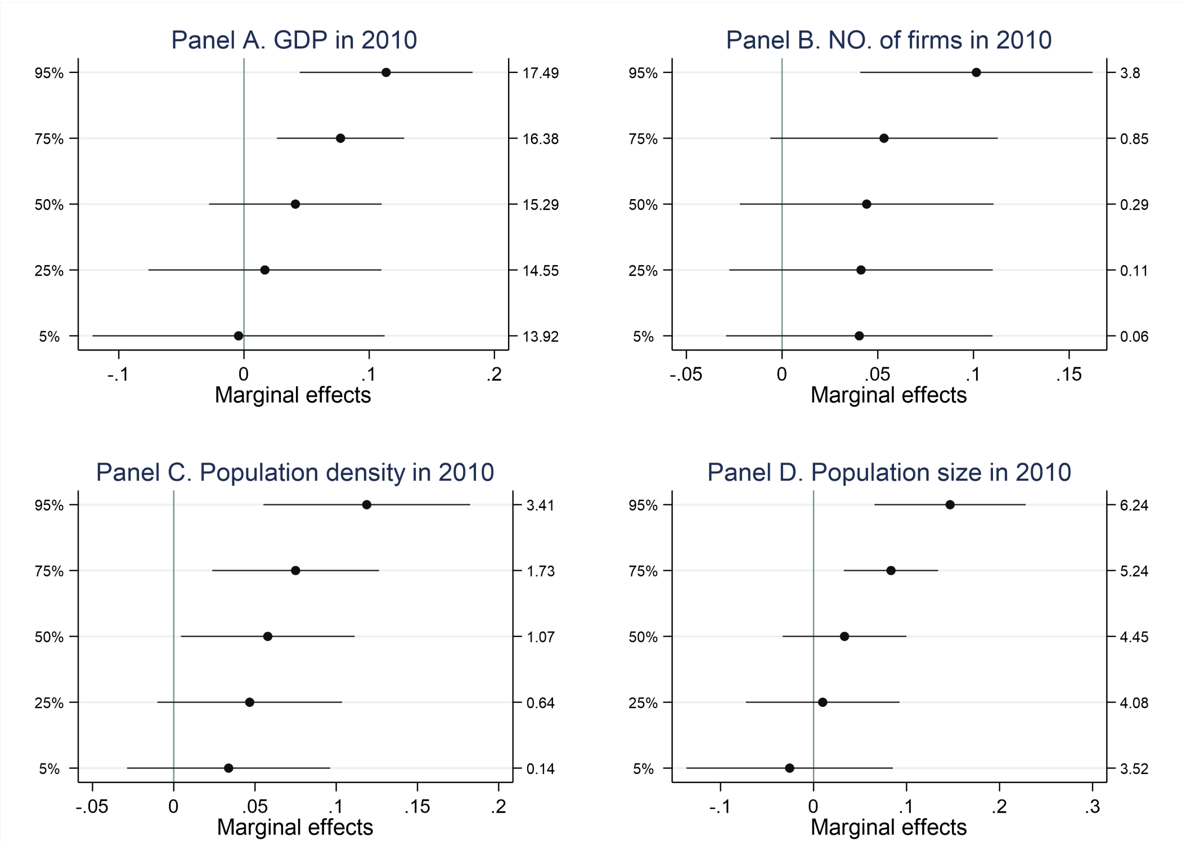
The impacts of annexation could depend on the characteristics of the central city. For example, the estimated average price-enhancing effect of annexation may only exist in a prefecture where the central city has a high economic or population density. In a prefecture with a weak central city, however, urban expansion via annexation may have no land-price effects. To check how the effect of annexation is related to the characteristics of the central city, we estimate the following equation:

$$\log Price_{ict} = \alpha + \beta * DUG_{ict} + \gamma * DUG_{ict} * CityChar_{2010} + \psi * X_{ict} + f_c + \delta_{pt} + \varepsilon_{ict}, \quad (9)$$

where $CityChar_{2010}$ represents the characteristics of a prefecture's central city in 2010, the start year of our sample period. Specifically, we choose four characteristics of the central city, including GDP, the number of industrial enterprises, population density, and population size in 2010.

We conduct the heterogeneous analysis in two steps. First, we follow the strategy of the event study and estimate (9) using the sample of treated counties only. Second, using the estimated coefficients, we calculate the marginal effect of the annexation according to the ranking of central cities by the above four characteristics. Panel A of Figure 7 portrays the marginal effect of the annexation (i.e., $\hat{\beta} + \hat{\gamma} * CityChar_{2010}$) if the central city's GDP is ranked at the 5th, 25th, 50th, 75th, and 95th percentile. The horizontal axis represents the marginal effect of the annexation on industrial land prices; the left and right vertical axes represent the ranking and value of the central city's GDP; the dots represent the calculated marginal effects; and the horizontal lines represent the 95 percent confidence intervals. As shown in Panel A, if the central city is ranked above the 50th percentile in terms of GDP, then annexing a peripheral county into the central city significantly increases industrial land prices in the county. However, if the central city has a smaller economy, at the bottom 50 percent in terms of GDP, then the marginal effect

Figure 7: Effects of annexation and characteristics of the central city



Notes: From the estimated equation (11), these marginal effects for each city characteristic are calculated as $\hat{\beta}+\hat{\gamma}*CityChar_{2010}$ at different percentiles of the city characteristic. The horizontal axis represents the marginal effect of the annexation on industrial land prices; the left and right vertical axes represent the ranking and value of the central city's characteristics inlcuding GDP (Panel A), the number of industrial enterprises (Panel B), population density (Panel C), and population (Panel D); the dots represent the calculated marginal effects; and the horizontal lines represent the 95 percent confidence intervals.

of annexation on industrial land prices is not significantly different from zero. Therefore, annexation seems to affect industrial land prices only if the economic size of the central city is large enough.

In Panel B, we rank all central cities according to the number of industrial enterprises and plot the marginal effect of annexation at different ranks. The annexation increases industrial land prices in the annexed counties only if the central city has a very large number of enterprises in the initial period. Panel C depicts the marginal effect of the annexation according to the ranking of central cities by population density. Only for central cities with a high population density, at the 50th percentile or higher, does annexation enhance industrial land prices in the treated counties. Finally, Panel D plots the marginal effect of the annexation according to the ranking of central cities by population size. Similar to Panel A, annexation has a significant effect only if the central city has a relatively large population size (at the 75th percentile or higher).

By including the control group in Columns (3) and (4) of Table 3, we run a DID regression of equation (11) and reproduce the plots in Figure 7. The results are similar. In sum, the effect of government-directed urban expansion may depend on some prerequisites. The annexation has a statistically significant effect on industrial land prices in the treated county only if the central city is already well developed.

7 Analysis of firm entry and investment

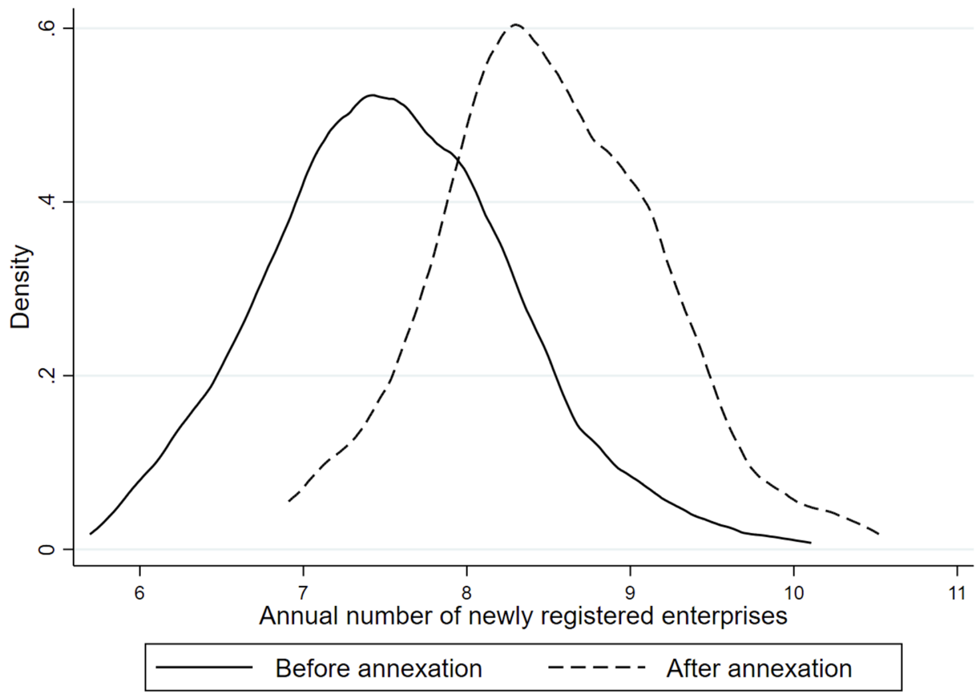
As shown above, our model also predicts that firm formation and investment will increase in the annexed county. In this section, we examine how annexation affects firm entry and investment. For firm entry, our sample period is also from 2010 to 2019, same as in the land price analysis; for investment, data are available only up to 2017, so the sample period is slightly shorter.

Before conducting formal statistical analysis, we first report descriptive evidence by plotting the distribution of the annual number of industrial and commercial enterprises newly registered in treated counties. The solid and dotted lines in Figure 8 portray the distributions before and after annexation. The distribution clearly shifts to the right, suggesting that annexation tends to increase the entry or formation of new enterprises.

We formally examine the effects of annexation on firm formation and report the results in Table 6. The dependent variable is the log number of new firm entries. Column (1) presents the estimated coefficient of the DUG dummy from the event study using the sample of counties annexed into the central city. Annexation significantly boosts the entry of new enterprises by 12.48 percent. Column (2) reports the results from the DID estimation adding the neighboring counties as the control group. It shows that the annexation increases the number of new firm entries by 6.22 percent. Finally, in Column (3), we also report a DID estimation using original central cities as the control group. It shows that annexation still increases the number of new entries by 7.11 percent. In sum, the annexed county experiences increased new-firm entry whether compared with itself before the annexation, its neighboring counties, or the original central city.

We next examine how annexation affects investment in the annexed counties, using

Figure 8: Distribution of newly registered enterprises before and after annexation



Notes: Figure 8 plots the distribution of the annual number of newly registered enterprises before and after annexation. The annual number is calculated using the SAMR data that spans the period 2010-2019.

Table 6: Effects of annexation on the number of newly registered enterprises, 2010-2019

DV: Log no. of newly registered enterprises	(1) Event study: using the sample of treated counties	(2) DID: using neighboring counties as the control group	(3) DID: using central cities as the control group
DUG	0.1248**	0.0622*	0.0711**
	(0.0552)	(0.0326)	(0.0343)
Controls	Yes	Yes	Yes
County_FE	Yes	Yes	Yes
Province_Year_FE	Yes	Yes	Yes
Observations	850	2280	1610
Adjusted R^2	0.832	0.944	0.974

Notes: This table reports the effects of annexation on the number of newly registered enterprises from 2010 to 2019. Column (1) presents the result of the event study using the sample of counties incorporated into central cities. Column (2) reports the result of the DID estimation by defining the control group as neighboring counties that are adjacent to the central city but were not annexed by the central city during the sample period. Column (3) reports the result of the DID estimation by defining the control group as central cities. Controls include the following 2010 county/district characteristics: log population, log GDP, share of second-sector GDP in total GDP, and urbanization rate. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Annexation and investment in fixed assets, 2010-2017

DV: ln(investment)	(1) Event study	(2) DID
DUG	0.0967*	0.1006***
	(0.0502)	(0.0387)
Controls	Yes	Yes
County_FE	Yes	Yes
Province_Year_FE	Yes	Yes
Observations	713	1908
Adjusted R^2	0.914	0.936

Notes: This table reports the effects of annexation on investment in fixed assets from 2010 to 2017. Column (1) presents the results of the event study using the sample of treated counties incorporated into central cities. Column (2) reports the result of the DID estimation by defining the control group as treated counties' neighboring counties that are adjacent to the central city. Controls include the following 2010 county/district characteristics: log population, log GDP, share of second-sector GDP in total GDP, and urbanization rate. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

log total investment in fixed assets at the county level as the dependent variable. Columns (1)-(2) in Table 7 report the coefficients of the DUG dummy from the event study and the DID estimation, respectively. Both columns show that annexation boosts investment in fixed assets by about 10 percent.

The evidence reported in this subsection suggests that the competition for land among new entrants following annexation is a reason for the increased land prices, as suggested in the theoretical analysis. By directing the expansion of central cities toward the annexed counties, governments effectively identified the likely areas for future city growth, reducing the incentive to postpone investment in these areas. With a rise in economic vitality following annexation, firms' expected returns as well as willingness-to-pay for land rise, leading to stronger competition for land and higher land prices.

8 Government practices in land markets

The relaxation of government intervention could be an alternative channel leading to increases in land prices. In China, upper-level governments have the power to determine the promotion of local political leaders according to local economic performance. Thus, local leaders are motivated to attract investments by implementing various policies such as administratively transferring industrial land at below-market prices. Leaders of counties, who have more autonomy, have stronger motivation than district leaders to adopt non-

Table 8: Effects annexation on land transaction modes

	(1)	(2)	(3)	(4)
	Event study		DID	
Dependent variable:	Share of trans. events through auctions	Share of trans. area through auctions	Share of trans. events through auctions	Share of trans. area through auctions
DUG	0.0429**	0.0429**	0.0215*	0.0173
	(0.0172)	(0.0181)	(0.0121)	(0.0120)
Controls	Yes	Yes	Yes	Yes
County_FE	Yes	Yes	Yes	Yes
Province_Year_FE	Yes	Yes	Yes	Yes
Observations	900	900	2365	2365
Adjusted R^2	0.222	0.197	0.221	0.194

Notes: This table reports the effects of annexation on land transaction modes. Columns (1) and (2) present the results of the event study using the sample of treated counties incorporated into central cities. Columns (3) and (4) present the result of the DID estimation by defining the control group as treated counties' neighboring counties that are adjacent to the central city. The dependent variable in Columns (1) and (3) is the share of transactions using bidding, auction and listing in the count of total transactions. Columns (2) and (4) is the share of transaction area using bidding, auction and listing. Standard errors are clustered at the county level. Controls include the following 2010 county/district characteristics: log population, log GDP, share of second-sector GDP in total GDP, and urbanization rate. Standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

market transaction modes, which is the main reason why we have controlled for land transaction mode dummies in our land price regressions.

In the following analysis, we ask whether land transactions through auction (the competitive market mode) increased after a county was annexed into the central city. If so, the greater use of auctions could constitute an additional reason for higher post-annexation industrial land prices.

Table 8 reports regression results using as dependent variables the share of transaction events using auctions as well as the share of land area transacted through auctions. Columns (1)-(2) present the results from the event study. Both coefficients are significantly positive, suggesting that transactions are more likely to occur through auctions following annexation. Adding land transactions from control counties to the sample, Columns (3)-(4) present the DID estimation results. Compared to those in Columns (1)-(2), coefficients of the DUG dummy in Columns (3)-(4) are smaller in magnitude and only marginally significant or insignificant at conventional levels.

The event-study results in Columns (1)-(2) show a rising use of auctions over time (between pre- and post-annexation years) in annexed counties, which reflects a national movement toward market-based transactions. The insignificant DID coefficient, however, shows that annexed and control counties were equally affected by this movement. As a result, the DID findings suggest that higher industrial land prices in annexed relative to control counties were not caused by an auction-based reduction in government price manipulation and that they appear to proceed equally across both types of counties.[17]

9 Conclusion

Urban expansion or sprawl as a result of market forces has been widely studied and attracted many critics in the U.S. and European countries (Brueckner, 2000; Patacchini and Zenou, 2009). However, empirical evidence on the effects of government-directed urban expansion is still lacking. Using a large-scale administrative reorganization in Chinese cities and detailed data on land-lease transactions, we investigate the impact of government-directed urban expansion on industrial land prices and new firm entry in annexed areas.

The results show that when the central city annexes an adjacent county, that county's industrial land prices rise by about 7 percent. This positive price effect does not come at cost of lower industrial land prices in neighboring counties or in central city itself. The annexation price gain reflects an improvement in the vitality of the local economy, captured by the entry of new firms and greater investment in fixed assets investment, which serves to push up land prices. Higher prices are unlikely due to a differential use of auctions, which were adopted in both annexed and treated counties, in step with a national reform. We also document some critical variations in the effects of the annexation across prefectures. We find that the effect of annexation on industrial land prices is more pronounced if the central city has a larger economy, or a higher economic or population density.

[17] One might suspect that increases in industrial land prices result from a decreased land supply following the annexation. To address this concern, we also examined whether the aggregate transaction volume of industrial land and the share of industrial land in the total transaction volume declined after the annexation. For both the event study and the DID specifications, the coefficients of the DUG dummy are never statistically significant and are positive in three out of four regressions, suggesting that decreased land supply is unlikely an explanation for increases in industrial land prices. These results are available upon request.

The wealth of information in our land transaction dataset allows us to examine the impacts of government-directed urban expansion in China, an urban growth policy widely used across developing countries but understudied in the literature. We believe that our results provide a comprehensive picture of how directed growth affects local industrial development in a large and important economy. Despite this progress, a lot more remains to be done. For example, it will be useful to know what exactly encouraged firm entry in the annexed county. Our motivating model has emphasized the benefits of expected improvement of infrastructure and reduced uncertainty following the annexation. In a sense, we view annexation as an implicit "development guarantee" in the annexed county (see Owens et al. (2020)). However, there is room for alternative explanations. It is also possible that entrepreneurs expect enhanced agglomeration economies (as a result of better coordinated urban and industrial planning after the annexation) or increased labor supply (as a result of the annexed county becoming more attractive to migrants). Disentangling these different channels empirically is likely to be a fruitful investigation. We leave it for future research.[18]

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[18] We also performed a parallel analysis to examine the impact of annexation on prices of residential and commercial land, both separately and jointly. The findings, presented in Table A.1 (see Appendix), indicate a positive effect on residential land prices, although only the DID coefficient shows statistical significance (albeit marginally). Combining the samples did not reveal any statistically significant effects. Upon reflection, we realized that in the residential and commercial land markets, newly available parcels compete closely with existing developments, potentially limiting significant price impacts. Conversely, in the industrial land market, the positive effect on prices primarily stems from the transacted parcels, given the difficulty in repurposing existing industrial facilities for new firms.

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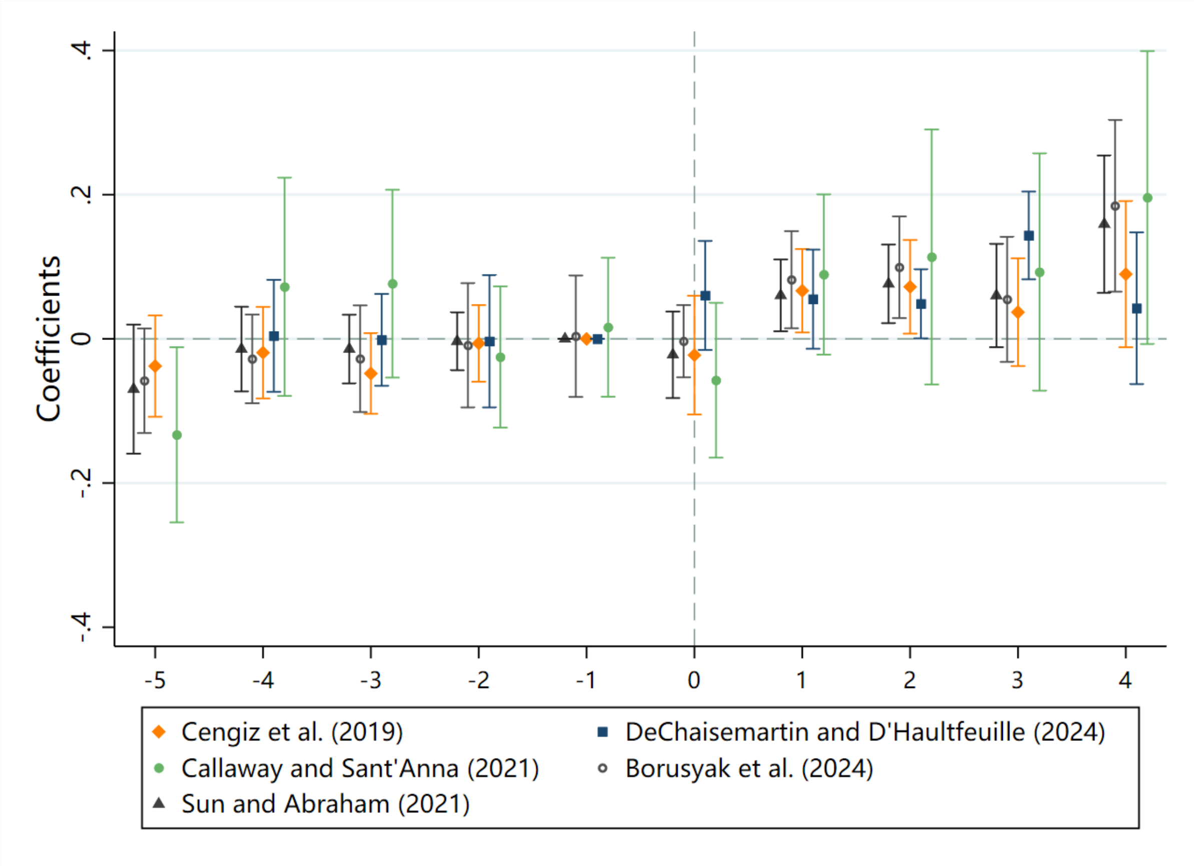
Appendix—Not for Publication

Figure A.1: Dynamic treatment effects: alternative estimators



Notes: Results from five heterogeneity-robust DID estimators are presented in this figure. The first one follows the approach used by, among others, Cengiz et al. (2019). Specifically, we first divide treated counties in our sample into different groups based on the treatment year; for each group, we use the never-treated adjacent counties as the control group. We then run a stacked regression with separate fixed effects for each group of treated units and their controls. The next three methods, instead of estimating the effects from the stacked data, estimate cohort-specific effects first and then aggregate them up, with Sun and Abraham (2021) and Callaway and Sant'Anna (2021) using each cohort's relative frequencies as weights to compute a weighted average and de Chaisemartin and D'Haultfœuille (2024) computing a simple average. The final estimator applies the imputation method by Borusyak et al. (2024). A two-way fixed-effects model of land prices (as specified in equation (10)) is first fitted using untreated counties' data. This model is then used to predict counterfactual land prices for treated counties. The difference between actual and counterfactual prices provides the estimated treatment effect.

Table A.1: Effect on residential and commercial land prices

	(1)	(2)	(3)	(4)	(5)	(6)
	Residential land		Commercial land		Residential+commercial land	
D.V.: ln(price)	Event study	DID	Event study	DID	Event study	DID
DUG	0.0390	0.1289*	-0.1641**	-0.0536	-0.0408	0.0845
	(0.1037)	(0.0774)	(0.0687)	(0.0522)	(0.0753)	(0.0612)
Parcel-level controls	Y	Y	Y	Y	Y	Y
Price_trend	Y	Y	Y	Y	Y	Y
County_FE	Y	Y	Y	Y	Y	Y
Province_Year_FE	Y	Y	Y	Y	Y	Y
Observations	21,820	65,218	9,717	23,743	31,542	88,964
Adjusted R^2	0.696	0.688	0.482	0.499	0.637	0.634

Notes: These analyses parallel those reported in columns (2) and (4) of Table 3 in the main text. Columns (1), (3), and (5) report the results of the event study using the sample of treated counties incorporated into central cities. Columns (2), (4), and (6) report the results of the DID estimation by defining the control group as treated counties' neighboring counties that are adjacent to the central city. Parcel-level controls include transaction mode dummies, land grade, land area, leasehold length, level of the government that approved the land transaction, and distance to the county center. Price trend is controlled by the interaction terms between year dummies and the county's median land price in 2010. Standard errors are clustered at the county level. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.