Subsidizing High-Rises for Growth or Vanity? An Empirical Assessment of Chinese Skyscrapers

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Abstract

More than half of the world's skyscrapers were built after 2000, predominately in developing countries. In this paper, we present new stylized facts summarizing the substantially weaker responses of these new high-rises to economic fundamentals in developing countries, which suggest that the traditional land–capital substitution explanation only weakly accounts for the new placements. Using spatially matched skyscrapers, land transactions, and new business entry data from China, we employ a political economy lens to explain the country's recent high-rise boom, which accounts for 59.8% of the world's high-rises built since 2000. We find that local governments in China incentivize the creation of new urban agglomerations by offering developers huge discounts on land prices in non-central locations—particularly in cities where local leaders are driven by stronger career incentives and during the period of the central government's monetary easing policy. Yet our finding that subsidized skyscrapers generate almost no spatial spillovers in the form of a land price premium or new business creation calls into question the effectiveness of state-engineered urban development.

Keywords: Skyscraper, government subsidy, spillovers, land value, misallocation, China

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1 Introduction

The past two decades represent a second "Golden Age" of global skyscraper development. Since 2000, 2,625 skyscrapers have been built around the world, accounting for 56.4% of the total number. The remarkable speed and scale of construction exceed the first wave of the high-rise boom in early 20$^{\text{th}}$ century America. Developing countries are now driving the race to update their skylines: 77.1% of new high-rises are in Asia (59.8% in China alone). In this paper we seek to fill in the research gap on the recent skyscraper boom by providing the first systematic empirical evidence on the causes and consequences of skyscrapers in the developing world.

We begin by documenting three novel stylized facts that summarize the discernible relationships between a country's economic fundamentals and skyscraper development in developed vs. developing countries. First, we evaluate a global dataset of skyscraper projects covering 18 countries from 1970 to 2018, and confirm that while the height of tall buildings increased with city population in both groups of countries, this relationship is much weaker in developing countries. Tall building heights in the US and Europe are about twice as responsive to city population size as in China and other Asian developing economies. Second, we compile detailed data on land price and local business locations in the United States and China, which together built 82.8% and 72.1% of the world's skyscrapers before and after 2000, and confirm that skyscrapers in China are less likely to be built near city centers and respond less to local land value than their American counterparts. For example, the estimated height-to-land-value elasticity for Chinese skyscrapers is merely 7.3%, less than half of that of the US city of Chicago (18.8%). Finally, there is a US–China gap in height–land value elasticity for commercial, but not residential, buildings.

We offer an explanation of these stylized facts using a political economy lens, which highlights local governments' role in decisions about whether and where to construct skyscrapers in developing countries. Assessing the case of China, we discover that many skyscraper projects, instead of being driven by market forces, were incentivized by local government subsidies to locate in smaller cities and non-central locations, where land is not expensive enough to justify the land–capital substitution by building vertically. Various accounts from government papers and news reports provide anecdotal evidence to explain the incentive behind the local government's "visible hand"—to promote high-end service agglomeration by subsidizing high-rise commercial centers. Consistent with this explanation, government subsidies are directed to the development of commercial buildings, but not residential ones, which presumably generate fewer agglomeration effects.

We then provide empirical evidence to support our political economy explanation, using China's recent skyscraper boom as a case study. First, we use the price discounts that local governments have granted to skyscraper developers in the land transactions to proxy for subsidies to these projects. Much prior research has shown that by exploiting their discretionary power over the allocation of urban land, local governments often manipulate transaction prices to influence developers' location choices in an attempt to fulfil their urban development plans (Wang et al., 2020). By matching land transaction records from 2003 to 2015 to the universe of tall buildings constructed in China between 2006 and 2012, we infer the magnitude of this discount from the price difference between land parcels used to build skyscrapers and nearby plots, which were assumed to have similar characteristics and therefore a comparable market value. We confirm that the land price discounts granted to skyscraper projects are sizable—an estimated 51.9% of the average transaction price. Our control group (tall residential buildings) received no such discount.

Our heterogeneity tests highlight on the political factors behind this subsidized skyscraper development. We show that the price discounts for skyscrapers are negatively associated with a city's economic fundamentals, such as proximity to the central business district (CBD),[1]

[1]Anecdotal evidence suggests that the heavily subsidized skyscraper projects often located in the new towns of the urban periphery and smaller cities, the sites of which were not economically viable but important to showcase the political achievement of the local officials.

but are positively associated with both the city mayor's career incentives (proxied by his/her estimated likelihood of promotion) and the central government's 4 trillion RMB stimulus plan.

Next we evaluate the economic consequences of these subsidized skyscraper projects—particularly whether these subsidies pay off in the future by generating considerable positive spatial spillovers. We first use the change in nearby land prices after the completion of the skyscraper projects to proxy for the spatial spillovers, assuming that any external benefits (or costs) of skyscrapers on nearby areas will be capitalized in the land value. To alleviate the concern that excessive government intervention in the land market could distort land prices to such an extent that they no longer accurately reflect the intrinsic economic value of the land parcels, we also employ two other proxies—the number of new firms registered and the number of local business amenities—to measure spatial spillovers. To identify the spillover effects, we exploit the temporal variation in skyscraper completion and the fine-grained spatial variation in the buildings' locations in a spatial difference-in-differences (DID) research design to compare the change in land price upon completion in neighboring areas (within a 2km radius around a newly built skyscraper) with that in areas slightly farther away (2–3km radius). Although neither of these variations was random, our DID estimate would be unbiased unless time-varying endogenous factors that coincide with skyscraper completion also vary sharply within a narrow radius around the new skyscrapers. To ensure that this is not the case, we control for a host of parcel characteristics and amenity variables, and flexibly include the interaction terms between the time trend and the latitude and longitude difference between the nearby parcel and the skyscraper.

Our estimates show that skyscrapers generated very localized spillover effects by merely increasing the land value, the number of new firms, and local business amenities within a 1km radius of the skyscrapers; these effects attenuate quite rapidly after 3 years. More importantly, the very localized spatial spillovers measured by either proxy are almost exclusively for *unsubsidized* skyscrapers, which calls into question the effectiveness of state-engineered urban development. By and large, these spillovers are highly dependent on location: high-rises in central locations with high productivity and availability of amenities accommodate the strong demand for space, and thus create substantial agglomeration benefits. On the contrary, attracting skyscraper projects to smaller cities and non-central locations where space is not in limited supply fails to achieve the intended positive spillover effects. We provide further evidence that corroborates these findings. We show that the high-rise office building vacancy rate is positively associated with the size of city-wide skyscraper subsidies. Analyses of potential mechanisms reveal that the lack of spillovers is not only driven by ill-chosen locations, but also by the poor development of real estate projects: subsidized skyscrapers are found to be in the hands of developers with a higher risk of capital-chain rupture, and make slower progress. Moving beyond the local effects, a city-level analysis confirms that skyscrapers did not confer short- or long-term benefits on wider regions. To ensure the robustness of our DID estimations, we conduct a battery of falsification tests to further validate the research design. The event study analyses detect no diverging pre-trends in the main outcomes and thus no significant anticipation effects. Nor do new skyscrapers generate confounding supply responses in the land market. Selecting counterfactual locations at random from a 5km radius area from a skyscraper's site, a spatial randomization inference test demonstrates that the results are not spurious.

Finally, we apply an illustrative welfare analysis to evaluate the cost and benefit of subsidizing skyscrapers, primarily from local governments' perspectives. Using the previously estimated land price discount rate of 51.9%, a skyscraper, on average, costs taxpayers around 175.7 million RMB in implicit subsidies. The average benefit in the form of land value appreciation ranges from zero (if we take the statistically insignificant estimate as zero) to 141 million RMB. Therefore, a subsidized skyscraper leads to an average estimated net loss of 34.7 million RMB (5.1 million USD).[2] The heavy subsidies for projects in non-prime

[2]Our calculation of benefits assumes that land value appreciation for parcels transacted before skyscraper construction is zero.

locations lead to a misallocation of resources. Unsubsidized skyscrapers (which were built in response to competitive market forces) have done a good job of allocating resources and yielding positive returns. Our results cast doubt on the widespread belief in developing countries that government interventions in high-rises can help spur urban growth.

This paper contributes to three strands of the literature. First, it advances a nascent literature on vertical urban structure (see Ahlfeldt and Barr (2020*a*) for a recent review of "skyscraper economics"); previous urban economics studies have mostly focused on horizontal urban land use patterns (Duranton and Puga, 2015). Within the neo-classical framework, skyscrapers are considered as the outcome of supply-side land–capital substitution, namely, substituting expensive land with heights (Barr, 2010; Ahlfeldt and McMillen, 2018). In addition to the economic fundamentals, a dissipative competition between rival skyscraper builders constitutes an alternative explanation to rationalize the rise of skylines (Helsley and Strange, 2008; Barr, 2012; Barr, 2013). Our study is the first to provide novel stylized facts and Chinese evidence that government interventions (rather than market forces) are behind the recent skyscraper boom in developing countries.

While prior work has focused on the determinants of height profile, few studies have produced systematic empirical evidence on the economic impacts of skyscrapers and the broader benefits they might generate. A small strand of research Liu et al. (2018) and Liu et al. (2020) has engaged in the first theoretical and empirical investigation of within-building agglomeration economies. These studies explore the vertical rent gradients and firm sorting of 93 skyscrapers located in 18 metropolitan areas in the United States, and identify within-building localized productivity spillover. Curci (2015) explores whether there is a positive relationship between the number of skyscrapers in US cities and their urban productivity growth, and suggests that high-rise buildings are a new source of agglomeration economies. More than 40 years of research on US and European cities notwithstanding (Glaeser and Henderson, 2017), our paper adds to this literature by studying a large developing country, China, and thus greatly enriches the geographical profile of studies on skyscrapers. To the best of our knowledge, this paper is among the first empirical studies to estimate the spillover effects around tall buildings. Moreover, China's fine variations in skyscraper construction across time and cities present a unique test case for assessing the impact of skyscrapers.

Finally, our research links to political economy studies on the role of local governments in China's urbanization process. Scholars have suggested that political centralization and economic regional decentralization incentivize local leaders to engage in tournament competition by strategically leveraging investments (Xu, 2011; Yu et al., 2016). Skyscraper development in China has been heavily influenced by local officials' career incentives as well as economic fundamentals (Barr and Luo, 2020). As the sole seller of land, local governments can directly invest in mega-projects with land as an input, or be indirectly involved by offering a discount to the buyers in charge of project construction. Government-led investments and subsidies are often considered to be a main source of capital misallocation in China (Hsieh and Klenow, 2009; Song et al., 2011). This paper estimates the magnitude of skyscraper construction subsidies granted by local governments. By exploring the heterogeneous effects depending on the extent of government involvement in skyscraper development, we shed light on heated debates about the effectiveness of such state-orchestrated urbanization drives.

The remainder of the paper is organized as follows. Section 2 introduces the data and presents new stylized facts. Section 3 describes the empirical strategies, and Section 4 presents the results. Section 5 discusses several potential mechanisms as well as the welfare implications of our findings. Section 6 concludes.

2 Data and Stylized Facts

2.1 Data

Our analyses combine data from two main sources: (1) a worldwide skyscraper database and (2) land transaction records in China's primary land market. In this section, we describe each source in detail and summarize key variables and sample definitions.

Skyscraper Data We obtain data on skyscraper development from Emporis.com and the Council on Tall Buildings and Urban Habitat (CTBUH). They contain the most comprehensive information on tall buildings to date; both are commonly used in the literature (see, for example, Barr, 2013; Ahlfeldt and McMillen, 2018; Barr and Luo, 2020).

We extract information on newly completed buildings with a fixed height of more than 100m in China[3] from 2006 to 2012 from the global skyscraper database. This provides detailed building-level information on height, specific uses (business, residence, hotel), completion time, and precise addresses, which we used to geo-code each skyscraper's latitude and longitude.

Skyscraper Development in China China's rapid urbanization since 2000 has coincided with an unprecedented growth in the number of tall buildings. Figure 1 illustrates that in 2018 alone, a record number of 143 buildings over 200m tall were completed worldwide: 62% (88 high-rises) were in China. Five of the world's 10 tallest buildings, and 44 of the 100 tallest, are in China.

[Figure 1 about here]

We assembled a sample of 517 tall buildings during our study period (2006–2012). Of these, 208 are for commercial use (i.e., skyscrapers), and the rest are residential buildings. This recent wave of tall building construction, accounting for approximately 30% of the total number of skyscrapers in China, displays rich regional and temporal variation. Figure 2 illustrates the geographic distribution of the 208 skyscrapers: 111 are located in coastal areas, 66 in the central area and 31 in the western area. In sharp contrast to the bustling construction, a recent survey estimates the average office vacancy rate in tier-1 and tier-2

[3]China's "Uniform Standard for Design of Civil Buildings" issued by the Ministry of Housing and Urban–Rural Development in 2019 defines a skyscraper as a building with business functions and a fixed height of more than 100m.

cities at only 21.5% in the third quarter of 2019 (Shepherd et al., 2020).[4] A natural question is therefore whether Chinese cities, especially lower-tier cities, need so many commercial high-rises.

[Figure 2 about here]

Noting the significant construction costs and high vacancy rates of very tall buildings, China's National Development and Reform Commission issued a circular in 2020 strictly prohibiting ultra-high skyscrapers (over 500m) and urging local governments not to pursue excessive construction. However, the momentum of skyscraper construction has not abated.

Land Transaction Records We compiled land transaction data from the official website of the Land Transaction Monitoring System (www.landchina.com), which is maintained by the Ministry of Natural Resource's Real Estate Registration Center. This data covers almost all land transactions in China's primary land market from 2003 to 2015. For each transaction, it includes detailed information such as the location, price, size of parcel, type of transaction,[5] land use type (residential, commercial, industrial, or mixed use), land quality, and buyer and seller. We convert each parcel's address into geo-referenced latitude and longitude coordinates using China's leading search engine, Baidu Map API,[6] which allows us to integrate each land transaction into a geographical information system (GIS) environment. We merge this data on the land parcels with a battery of locational characteristics includ-

[4]The "China City Tier List" published by the *South China Morning Post* in 2018 classifies 338 Chinese cities into four tiers on the basis of population, GDP and administrative hierarchy. Tier-1 cities include Beijing, Shanghai, Guangzhou, and Shenzhen.

[5]Transactions can be carried out in one of the four ways: two-stage auction (*guapai*); invited auction (*zhaobiao*); English auction (*paimai*); or bilateral agreement (*xieyi*).

[6]Source: https://api.map.baidu.com/lbsapi/.

ing the distance to the CBD,[7] schools, public parks, and public transportation facilities. To control for time-varying embedded price premiums due to each high-rise's proximity to consumption amenities, we built a distance matrix among parcels and consumption amenity points of interest (POIs) based on the 2010 and 2015 locations of restaurants, hotels, retail establishments, recreation facilities, and medical services.[8]

Land for Skyscraper Construction We match each skyscraper to the land parcel on which it was built in two steps. First, we employ the geo-coded information to select land parcels that were in close proximity (with a 5km radius) to the skyscraper and transacted at least 2 years prior to its completion. Then, we manually perform the second-round matching by checking whether the recorded land buyer is consistent with the skyscraper's developer information. The intersection of the two matching procedures yields a final matching rate of 58%. Table 1 reports the descriptive statistics of the 120 precisely identified land parcels for skyscraper construction. Yet since the Ministry of Land and Resources has only mandated the reporting of land transaction information since 2007, for transactions before that time or those with a longer construction period we might be unable to find a match in the land transaction records.

[Table 1 about here]

[7] Using the 2010 Global Radiance Calibrated Nighttime Lights published by the National Oceanic and Atmospheric Administration National Geophysical Data Center, the nighttime lights with no sensor saturation enable us to identify the brightest cell in each city's urbanized area, which is defined as the CBD.

[8] The 2010 and 2015 POI data were acquired from the China Geographical Information Monitoring Cloud Platform maintained by the National Geomatics Center.

2.2 Stylized Facts

According to neoclassical theory, the land–capital substitution in building service production is the fundamental driver of skyscraper development (Epple et al., 2010; Ahlfeldt and Barr, 2020*a*): height is substituted for expensive land in a purely economic sense. Urban land value rises with proximity to the CBD, and increases with the city size and density (Albouy, 2008; Albouy et al., 2018; Combes et al., 2019). Thus if land–capital substitution was indeed the most important driving force behind the high-rise development, skyscrapers should be more likely to be built in large cities and around the CBD (Ahlfeldt and Barr, 2020*b*). Below we document several stylized facts comparing skyscraper development across developed and developing countries, and illustrate that the patterns of the most recent wave of skyscraper construction in developing countries, most notably China, distinctively deviate from the predictions of classic urban models and contrast with those of developed countries.

Building Height–City Population Relationships We begin by presenting the global patterns of skyscraper development. As shown in Figure 1, tall building construction has been shifting from North America to Asia since the mid-1980s. China's skyscraper boom represents the most obvious example. We find substantial deviation in skyscraper construction in developing vs. developed countries. Figure 3 plots the relationship between city size and the mean height of the 10 tallest buildings across 117 cities in four regions: United States, Europe, China and other Asian developing economies. The figure indicates a strong relationship in the US and Europe: an increase of 10 million in metro population predicts an additional 270m increase in average skyscraper height in the US and 250m in Europe. This pattern is consistent with land–capital substitution: urban land value tends to increase with city size, which encourages building vertically.

[Figure 3 about here]

However, the height–city population connection is much weaker in China and other developing economies in Asia, such as the United Arab Emirates and Malaysia. The estimated coefficients are roughly half as large as those found in developed countries: when the urban population grows by 10 million, the average height of the ten tallest buildings increases by only 140m in China and 120m in other Asian developing economies. This also agrees with the pattern in Figure 2: skyscrapers in China are no longer concentrated in tier-1 cities or provincial capitals. A considerable proportion of skyscraper projects from 2006 to 2012 were located in smaller cities.

Height Gradient Another prediction of land–capital substitution is that skyscrapers should be more economically justified to be built near the CBD. In the second empirical exercise, we compare the height gradients of skyscrapers in a developing country (China) and a developed country (US). We regress the logarithm of the skyscraper height and commercial land price on the logarithm of its distance to the CBD and a host of other covariates. Table A1 reports the results. In China, the estimated height gradient to distance is -0.042, along with a much steeper price gradient (-0.422). By contrast, the height and price gradients of skyscrapers in the major US city of Chicago are in line with each other (-0.411 and -0.541, respectively) (Ahlfeldt and McMillen, 2018). Taken together, the height gradient of Chinese skyscrapers is much flatter than their American counterparts.

This finding corroborates the distribution of the tallest buildings by distance from the CBD in Chinese cities (Figure 4). While some of the highest buildings are located close to the CBDs, several are in new towns and suburban districts where land prices are much lower than in CBDs.

[Figure 4 about here]

Land Price Elasticity of Height The next stylized fact is the height–land value elasticity. To quantitatively estimate how skyscraper development has responded to land costs across countries, we employ the following reduced-form empirical specification in the spirit of Ahlfeldt and McMillen (2018):

$$\ln(S_{jt}) = \alpha_t^E + \beta_1^E \ln(\hat{r_{it}}) + \varepsilon_{it}^E \tag{1}$$

where the dependent variable $\ln(S_{jt})$ is the logarithm of the building height of skyscraper (j) built in year (t). α_t^E denotes year fixed effects. $\ln(\hat{r_{jt}})$ is the logarithm of the predicted land value at the skyscraper site imputed based on the transaction price of nearby land parcels.[9] We use predicted land value rather than the actual transaction price of the land parcel for skyscraper construction because the latter might be heavily subsidized and thus may not reflect local fundamentals. ε_{it}^E is a random error term.

For a meaningful cross-country comparison, we perform a parallel empirical estimation of the land price elasticity of building height in Chicago, restricting the sample to buildings over 100m that were built during the same period as the Chinese sample. Again, we conduct the analysis separately for skyscrapers and tall residential buildings.

To interpret β_1^E as the demand-side response of skyscraper construction to land cost, we need to tackle a classic simultaneity issue: unobserved supply-side factors like soil conditions might directly affect the building height and land value in tandem. Another concern is measurement error in the predicted land value.[10] To address these concerns, we instrument

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[9]The predicted land value is defined as $\hat{r_{jt}}=\sum_{i=1}^{n}\left(\frac{D_{ij}^{-1}}{\sum_{i=1}^{n}D_{ij}^{-1}} \times r_{it-m}\right)$, where n represents the number of nearby land parcels with similar characteristics, D_{ij}^{-1} is the reciprocal of the Euclidean distance between land parcel (i) and skyscraper (j) $(D_{ij} < 2.5km)$, and r_{it-m} is the unit price of land parcel (i) transacted $(m \in [0,3])$ years prior to the skyscraper's construction time (t).

[10]We consider two main sources of measurement errors in this regard. The first stems from random fluctuations in land price, which tend to attenuate the ordinary least squares (OLS) estimate of height–price elasticity towards zero. The second source is closely related to the prediction approach. Expensive land parcels in the CBD are more likely to be underestimated

land value with demand shifters such as distance to the CBD and the nearest amenities (public parks and train stations) in the Chinese sample and distance to the CBD and Lake Michigan in the Chicago sample, following the practice of Ahlfeldt and McMillen (2018).

Table 2 reports the results. Our preferred instrumental variable (IV) estimates suggest that the average elasticity of skyscraper height with respect to land price is 0.073 in China, which is much smaller than in Chicago (0.188), but the estimates are similar for tall residential buildings (0.165 and 0.169, respectively). These patterns indicate that the Sino–US gap in the responsiveness of skyscraper construction to land costs cannot be driven by cross-country differences in land–capital substitution elasticity or the engineering costs associated with building up, which would generate a similar gap in the estimated height–price elasticity for tall residential buildings as well.[11] Therefore, we conclude that the substantial gap we observe is attributable to factors that lie outside the competitive market framework.

[Table 2 about here]

Price–height elasticity captures responses at the intensive margin. We also preform similar analyses along the extensive margin on the Chinese sample by estimating how the placement of tall buildings responds to land value, regressing the number of skyscrapers on pre-

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if few land transactions can be observed in that neighborhood, and thus cheaper parcels further away were used as a match. This might produce a downward bias in OLS estimates, although we further include a control variable, the distance between the CBD and land parcels, for prediction.

[11]In a canonical model of tall building service production function developed by McDonald (1981) and Ahlfeldt and McMillen (2018), the height elasticity to price is denoted by $\beta = \sigma/(1 + \theta - \lambda)$. Hence, in a competitive market framework, the magnitude of elasticity ultimately depends on three key parameters: the elasticity of land–capital substitution (σ), the elasticity of construction costs with respect to building height (θ), and the elasticity of extra space with respect to building height (λ).

dicted land value at the 1km×1km grid cell-by-year level. Table 3 presents the OLS and IV estimates of the extensive margin elasticities. Reassuringly, the pattern is robust: the price–quantity elasticity for skyscrapers (0.028) is much smaller than that of tall residential buildings (0.046).

[Table 3 about here]

Overall, these stylized facts suggest that economic fundamentals play a much less important role in driving skyscraper growth in developing countries. Anecdotally, mayors and governors in such countries are more eager to mark their cities on the map by building high-rise commercial properties. Previous studies have also pointed out that where political accountability is weak, leaders of developing countries tend to pursue private interests from such projects (Gjerløw and Knutsen, 2019). Despite these plausible alternative explanations from various contexts, in this paper we present further evidence that the spatial misallocation of skyscrapers exists not only across cities but also within them, and explore its association with government interventions in China.

3 Why Do Developing Countries Build Skyscrapers?

In the previous section, we documented three sets of stylized facts related to global skyscraper construction: (1) The positive skyscraper height–city population relationship is much weaker in developing countries; (2) Skyscrapers in China are less likely to locate near city centers than those in the US, and they are also less responsive to land prices; (3) The Sino–US gap in the building height elasticity to land price exists for commercial skyscrapers, but not tall residential buildings. These facts suggest that non-market forces could play a greater role in decisions about whether and where to build skyscrapers in developing countries, with China as a prime example. Moreover, substantial non-market forces seem to motivate locating Chinese skyscrapers (but not tall residential buildings) in smaller cities and non-central areas. An obvious explanation is that a government subsidy is attracting skyscraper developers to base their projects in non-central locations in hopes of creating new urban agglomeration. In this section, we empirically investigate the existence of such a subsidy. In Sections 4 and 5, we further evaluate the cost effectiveness of subsidizing skyscrapers by quantifying their spatial spillovers.

3.1 Anecdotal Evidence on Skyscraper Subsidies

Local governments have heavily influenced China's remarkable growth of vertical structures. To explore the purpose of and approaches to implementing such interventions, we compiled official documents issued by a number of Chinese cities (such as Nanjing in 2007, Liuzhou in 2012, Qinzhou in 2013, and Wenshan in 2019[12]) to promote super high-rise projects. The anecdotal evidence reveals that local governments tend to intervene in the skyscraper market through a toolkit of policies including land discount, tax reductions and cheap credit. The land price discount is among the most commonly used, largely because city leaders have substantial control over urban land supply and development (Lichtenberg and Ding, 2009; Wang et al., 2020).[13] Although land sales must be made via market auctions, the choice of auction format is usually flexible and local governments can attach certain conditions during the bidding process to help skyscraper developers secure the land. As such, the transacted price tends to be much lower than it would be in a competitive auction.[14]

[12]Source: http://www.ynmg.gov.cn/info/1583/55246.htm.

[13]In China, the state owns the land, and sub-national governments are the sole sellers in the local primary land market. Local governments in China convey land to market entities by commoditizing and leasing land use rights in long-term contracts (40, 50 or 70 years).

[14]For example, local governments might implement a two-stage auction, which calls for the participation of one or two bidders in the first stage, and the nominal auction price is confirmed in the second step. Cai et al. (2013) has documented a positive and substantial price difference between English auctions and two-stage auctions.

The government documents and news articles we analyzed for this study emphasize three primary motivations behind the avid support for skyscraper development in China. First, cities seek to demonstrate their urbanization achievements and improve their urban image by building high-rises.[15] Municipal governments highly value the "landmark" effects that skyscrapers generate, which they anticipate will attract visitors and residents—especially skilled workers and "high-end" industries—to their cities. Small cities utilize skyscrapers to set them apart from their competitors in the region, while larger cities are more likely to build them on the urban periphery to boost new town development. Second, skyscraper construction is perceived as a powerful engine for local economic growth, and is thus inevitably intertwined with local government officials' career concerns (Xu, 2011). Barr and Luo (2020) document a positive relationship between officials' promotion incentives and skyscraper construction. Finally, since the fiscal decentralization reform in the mid-1990s, local governments have sought extra-budgetary revenue—especially from land revenue—to finance local expenditures. Local governments therefore tend to place skyscraper projects in new towns that have large quantities of undeveloped land. They then strategically develop the areas near the skyscrapers for commercial or residential use with an expectation to sell them at a premium. In summary, these institutional features—regional competition, career promotion and land revenue—shape Chinese skyscraper construction beyond the conventional market forces of demand and supply, constituting another layer of research interest.

3.2 Discounted Land Price for Skyscraper Construction

We seek to accurately quantify the empirical magnitude of the land discount granted to skyscraper developers. To do so, we generate a spatially matched sample of transactions involving land parcels for skyscraper construction (skyscraper land, hereafter) and other sur-

[15] Source: https://www.scmp.com/property/hong-kong-china/article/2070761/chinas-obsession-skyscrapers-reaches-new-heights.

rounding land parcels (non-skyscraper land, hereafter) that were sold before the skyscraper was built (see Figure A1). The geo-matching radius is initially set to 5km. Conditional on observed land characteristics and amenity access, we assume that these parcels are highly comparable in quality and underlying market value. In other words, non-skyscraper land is taken as the benchmark group that is free of any government intervention. We then attribute any transaction price difference between skyscraper and non-skyscraper land to the preferential treatment that local governments gave the skyscraper projects.

We begin with a simple comparison of the parcel characteristics between the matched skyscraper and non-skyscraper land. As shown in Table 1, the two groups of land are similar on all other observables such as plot size, land grade and distance to the CBD. They differ only in price. The average transaction price of a skyscraper land parcel was 4,025 RMB per square meter, which was approximately 27.8% (or 1,549 RMB) less than that of non-skyscraper land parcels (5,575 RMB).

Empirical Specification We then follow the spatial matching approach of Chen and Kung (2019) and estimate the land price discount using the following regression:

$$\ln(P_{ijct}) = \beta_1^D SkyscraperLand_{ijt} + \gamma^D X_i + \theta_j^D + \alpha_{ct}^D + \varepsilon_{ijct}^D \tag{2}$$

where the dependent variable P_{ijct} is the land transaction price of parcel i within a 5km radius of skyscraper j sold by city government c in year t. The key explanatory variable of interest, denoted by $SkyscraperLand_{ijt}$, is a dummy variable equal to 1 if parcel i was used to construct skyscraper j, and 0 otherwise. The coefficient of interest is β_1^D. It indicates the difference in price of skyscraper vs. non-skyscraper land within small geographic areas. In all specifications, we control for a rich set of parcel-level covariates, including the logarithm of the land area sold and its squared term, land quality (15-grade classification), land use (commercial use or mixed function), the logarithm of the distance to city c's economic center, and access to amenities. We also include the spatial trend (the latitude and longitude differences between the parcel and the skyscraper × year trend) as a control to capture the potential unobservable factors correlated with distance Ahlfeldt et al. (2021). Furthermore, to compare only land parcels located close to the same skyscraper and sold in the same year, we control for skyscraper-matched group fixed effects θ_j^D and city-by-year fixed effects α_{ct}^D. Robust standard errors are clustered at the matched pair level. ε_{ijct}^D is an error term.

Result Table 4 presents the results of the estimation using Equation (2). Column (1) uses a matched sample within a 5km radius of the skyscrapers. The coefficient on the main indicator variable $SkyscraperLand_{ijt}$ represents a discount rate of 42.2% ($e^{-0.549} - 1$) and is statistically significant at the 5% level. Since selection bias concerns remain due to the non-random location choices of skyscrapers, we further restrict our analysis to a 2.5km radius for a more precise estimate of the degree of land discount. Column (2) presents the results of our preferred specification and sample. The estimated coefficient for $SkyscraperLand_{ijt}$ substantially increases and the R-squared rises to 0.838. The empirical magnitude of the land price discount received by skyscraper developers is 51.9% ($e^{-0.732} - 1$). In the previous section, we documented that tall residential buildings are more responsive to land value than commercial skyscrapers, which suggests the latter may be more heavily subsidized. We test this prediction by repeating the previous analysis on a matched transaction sample of land parcels used for tall residential buildings and their nearby land plots. The results, reported in columns (3) and (4), indicate that the opposite occurs: local governments sell land to construct tall residential buildings at a higher price. These findings provide compelling evidence of the price discount offered for skyscraper land in China.

[Table 4 about here]

Another concern regarding the interpretation of the estimates is whether the land price discount we document is linked to government–firm collusion and land market corruption disguised as support for skyscraper projects. To test this channel, we further explore the relationship between the magnitude of the estimated land discount and the background of skyscraper developers. We categorize developers into four groups: local real estate giants, state-owned city investment groups, foreign capital and others. Arguably, government officials could more easily collude with the first two types of developers. Table A2 reports the results. Column (1) regresses the estimated magnitude of the land discount on indicators related to the skyscraper developer's background. Column (2) serves as a robustness check by adding extra building-level covariates. The insignificant coefficients in columns (1) and (2) reveal no significant differences in land subsidies granted to developers with different ownership, which rules out corruption as an important driver of skyscraper subsidies.

Heterogeneity in Price Discounts for Skyscraper Land In a standard case of profit maximization, developers would not choose to construct skyscrapers in small cities or suburban districts where land is cheap, since these areas would have limited productivity advantages and access to amenities. Yet, local governments in China believe skyscrapers can advertise a city to the world and promote non-central locations. Consequently, they attempt to attract skyscrapers to areas that are not deemed economically viable, as noted in Figures 2 and 4.

We examine the heterogeneity in the offered subsidies and the role of some city-specific factors. The estimation results are reported in Table 5. Column (1) repeats our baseline results as the reference. Column (2) introduces an interaction term between the skyscraper land dummy and a measure of city j's population size in 2010 where skyscraper i was located, denoted by $SkyscraperLand_{ijt} \times CityPop_{j,2010}$.[16] The coefficient on the interaction term is positive and insignificant. Small cities seem to receive lower land prices for skyscraper projects, but this finding lacks statistical power. In a similar vein, we interact the skyscraper land dummy with a distance variable $DistCBD_{ij}$, which denotes the logarithm of the distance between the skyscraper and its nearest city economic center. The estimation results

[16]The urban population data were obtained from the 2010 population census maintained by China's National Bureau of Statistics.

in column (3) indicate that the price discount of land parcels for skyscraper construction is significantly larger for those located far from the city center.

[Table 5 about here]

Since local governments monopolize the land supply in China, we further examine local officials' incentives to provide subsidies to encourage skyscraper construction in their cities. Below, we briefly describe some important institutional details, based on which we construct the incentive measures. As city-level leaders, it has been well documented in the literature that party secretaries are mainly in charge of party affairs, and the mayor is the executive officer of the municipal government (Xu, 2011). Although the party secretary is the *de facto* highest-ranking official in the jurisdiction, the mayor is responsible for administrative affairs, including land development planning, capital investment and other resource allocation decisions. Moreover, Chinese municipal officials' career advancement is closely tied to the city's economic performance (Qian and Xu, 1993; Li and Zhou, 2005). In related work, city leaders with short tenure expectations were shown to have been rewarded with significantly increased promotion chances for initiating long-term investment projects such as subways, although they are unlikely to remain in office until the completion of the project (Lei and Zhou, 2022).

Against this political and economic background, we hypothesize that ambitious city leaders, especially mayors, have stronger incentives to support skyscraper construction to induce urban growth, with the ultimate aim of promotion. Column (4) formally tests this proposition by interacting the skyscraper land dummy with the municipal mayor's and party secretary's career incentive indicators, respectively.[17] We matched each skyscraper project

[17]To measure the mayor's and secretary's career incentives, we follow the estimation approach proposed by Wang et al. (2020): we regress the promotion dummy (which equals 1 if the city leader was promoted to a higher-level position by the end of their term) on the leader's characteristics. The estimated coefficients are used to predict the *a priori* promotion

in our sample with information about the mayor and party secretary who were in office when it started. The estimated coefficient of the mayor interaction term is significantly negative, while it is positive and insignificant for the secretary interaction term. These results confirm that mayors who are more likely to be promoted provided greater land price discounts to skyscraper projects in their jurisdictions, while party secretaries had very little influence on land allocation.

We next explore the response of skyscraper subsidies to a nationwide expansion in investment—the 2009 economic stimulus plan.[18] This plan greatly enhanced local governments' fiscal capacity to support skyscraper development. As noted in Figure 4, more (and higher) skyscrapers were built in suburban areas during the post-crisis period. Since approximately 90% of local government investments were financed through bank loans in 2009 (Bai et al., 2016), we collect data on new loans granted by commercial banks between 2007 and 2012. We then calculate the post-2009 bank loan growth rates at the city level, which we use to measure the size of each city's stimulus package. Column (5) interacts the skyscraper land dummy with this stimulus package indicator. The negative coefficient indicates that the economic stimulus plan magnified the land subsidy granted to the skyscraper project. Again, this supports the government intervention argument.

To ensure that the various interaction terms used in columns (2) to (5) are not highly correlated with each other, we include the five interaction terms together in column (6). The estimation results suggest that the heterogeneous pattern of discounted land prices remains robust; their standard errors are analogous to the separate estimations, as previously

likelihood of each city leader in the sample, which is used to proxy for their career incentives. Table A3 reports the results using a linear probability model and probit regression.

[18]In the wake of the 2007 global financial crisis, Chinese premier Wen Jiabao initiated a 4 trillion RMB stimulus package; its main component concerned infrastructure and construction projects (Chen et al., 2020).

reported.[19]

The relationship between land price discounts and skyscraper height elasticity Recall that we argue that government subsidies are relevant to the low elasticity of skyscraper height with respect to land costs in China. Now, we illustrate the relationship between these two. Because some cities have few skyscrapers, we combine the 42 cities in our sample into 26 groups according to size and geographic proximity to increase our statistical power (see Table A4 for more details). In a similar vein, we estimate the region-specific land price elasticity of height (β_1^E) as well as the land price discount ($-\beta_1^D$). Figure 5 presents the scatter plot of the relationship between these two measures. We observe that skyscrapers' land cost elasticity of height decreases with the level of discount in the land price. For instance, the subsidy rate and height elasticity of Suzhou (the best-performing prefecture-level city in China) are 0.9% and 0.096, respectively, whereas in a region composed of small cities in Guangxi, they are 65.1% and -0.004, respectively. Overall, Figure 5 verifies that government subsidies are an important explanation for the observed pattern of Chinese skyscraper construction.

[Figure 5 about here]

4 Economic Returns of Skyscrapers

Vacancy Rate The average vacancy rate for US Grade-A offices, which account for the main part of a skyscraper, was around 9% before Q1 2020 but increased to 15% in Q2 of that year due to the Covid-19 outbreak.[20] By contrast, in China the average empty rate was up to 25% in the pre-pandemic period (Shepherd et al., 2020). Guangzhou recorded the

[19] If the collinearity among interaction terms approaches 1, the variance of the coefficient estimate will approach infinity.

[20] US National Association of Realtors, "January 2021 Commercial Real Estate Market Trends and Outlook" survey.

highest vacancy rate of tier-1 cities at 19.5%. Among the tier-2 city group, Chengdu (the capital of Sichuan Province) and Changsha (the capital of Hunan Province) had the lowest and highest vacancy rates, at 14.8% and 40.2%, respectively. High vacancy rates critically challenge the efficiency expectations behind skyscraper construction. Using city-level data on office vacancy rates,[21] we compute the average vacancy rate for city groups shown in Table A4, and then plot its raw correlations with the land price discount ($-\beta_1^D$). Figure 6 Panel (a) illustrates the negative relationship between the magnitude of government intervention and the vibrancy of the local skyscraper leasing market.

[Figure 6 about here]

Empirical Specification As described in Section 3, local governments promote skyscraper development in hopes of attracting skilled labor and high-value-added firms, and creating productive local agglomerations. This section evaluates this rationale for offering skyscraper subsidies. We examine whether the arrival of skyscrapers increases the land value of surrounding parcels. Our strategy assumes that any external benefits (or costs) of skyscrapers on nearby areas are reflected in the value of adjacent land (Ahlfeldt and Kavetsos, 2014; Pope and Pope, 2015).

We generate a spatially matched sample of commercial-use land parcels transacted within 5 years before or after a skyscraper was constructed, excluding skyscraper land. In our preferred specification, we further restrict our sample to include only land parcels located within 3km of a skyscraper. We define the treatment areas as 2km-radius circles around each skyscraper, and the control areas as 1km-radius rings that circumscribe each treatment area. Figure A2 illustrates our choice of treatment and control groups. Our empirical specification is a spatial difference-in-differences (DID) setting that compares the changes in land value before and after a skyscraper was built between land parcels within 0-2km of the skyscraper (treated) and those within 2-3km (control). The choice of the treatment and

[21] Ibid.

control groups largely ameliorates concerns about endogenous skyscraper placement, and increases the comparability between the groups. The specification is:

$$\ln\left(P_{ijt}\right) = \alpha_{jt}^{P} + \beta_{0}^{P} D_{ij}^{1} + \theta_{0}^{P} D_{ij}^{2} + \left(\beta_{1}^{P} D_{ij}^{1} + \theta_{1}^{P} D_{ij}^{2}\right) * \mathrm{Post}_{ijt} + \gamma^{P} \boldsymbol{X}_{i} + \varepsilon_{ijt}^{P} \tag{3}$$

where P_{ijt} is the land value of parcel i in year t near a skyscraper j. α_{jt} is a skyscraper-matched-sample j-year t fixed effect, which captures macro-level shocks common to all parcels near the same skyscraper in year t. D_{ij}^{1}, D_{ij}^{2} are indicator variables of individual parcel i within the $0-1$ or $1-2$km radius around a skyscraper. The $2-3$km ring is the reference group. Post_{it} is an indicator variable of whether the parcel i transaction took place after the completion of the corresponding skyscraper. $\boldsymbol{X}_{i}$ is the observable individual parcel i's characteristics and its nearby amenity accessibility, and ε_{ijt}^{P} is the error term. The standard errors are clustered at the skyscraper-neighborhood level. The coefficient β_{0}^{P} and θ_{0}^{P} on the ring dummy captures any systemic differences in the land prices between the treatment and control groups of parcels before skyscraper construction. Our key parameters of primary interest are β_{1}^{P} and θ_{1}^{P}, which give us the local effect on the treated spatial rings and capture the potential decaying spillover effect generated by skyscrapers.

In choosing the size of the treatment and control areas, if we had a good idea of the true decay rate of the spatial spillover effects, we could precisely define the control areas as those just outside the spillover range. However, it is hard to project the spatial scale of the external impacts of skyscrapers *ex ante*. Notably, the closer the control group is to the treatment group, the more comparable it is to the treatment group in unobserved local factors, and the more likely it is to be exposed to spillover (or siphon) effects, which could lead to the underestimation (or overestimation) of the treatment effect. Therefore, we experiment with an alternative cutoff between the treatment and control rings to assess the sensitivity of our results. We use the alternative sample of parcels within a 3.5km radius of the skyscraper, from which parcels of the 2–2.5km buffer ring are removed, and parcels of the 2.5–3.5km ring are selected as the control group.

Results Table 6 presents the estimation results on the capitalization of the spillover effects in areas surrounding skyscrapers. In column (1), the coefficient on the interaction term "0–1km * Post" is 0.646 and statistically significant, suggesting that land parcels for commercial use located within 1km of a skyscraper sold for approximately 90% ($e^{0.646}-1$) more than the baseline after construction finished. The coefficient on "1–2km * Post" become much smaller and turned insignificant. This finding implies that skyscrapers generate sizable positive spillovers, which are reflected in the value of nearby land, yet the premium effect is very local and dramatically decays with distance from the buildings. Column (2) in Table 6 reruns the spatial DID analysis but uses land parcels located 2.5–3.5km away from a skyscraper as the control group. The main findings are relatively robust to this change. The magnitude of the coefficient on the treatment indicator "0–1km * Post" is 0.648, slightly larger and more statistically significant than that in column (1). This is consistent with our conjecture that where a skyscraper generates spillovers, selecting control groups that are geographically closer to the treatment group might attenuate the estimates downwards. In column (3), to address potential concerns over location advantage heterogeneity even within the narrowly defined ring, we add additional control variables—the latitude and longitude differences between the parcel and the skyscraper. The estimate of skyscraper spillover effects remains stable. Thus, column (3) is our preferred specification. The key question is whether such spillovers exist for *subsidized* skyscrapers. In other words, does the urban investment supported by heavy subsidies pay off? Column (4) interacts the treatment indicators with a subsidy dummy $Subsidy_j$, which denotes whether the skyscraper received any land price discounts.[22] A joint significance test for the coefficient of $D^1_{ij} *$ Post $*Subsidy_j$ in tandem with that of $D^1_{ij} *$ Post indicates that subsidized skyscrapers generate much smaller and statistically insignificant spillovers (28.4%$=e^{0.250}-1$). To more intuitively showcase the land misallocation, we plot region-specific skyscraper spillovers against the magnitude of the land price discount granted

[22] $Subsidy_j$ is a dummy variable equal to 1 if skyscraper (j)'s land value predicted in Section 2.2 is higher than the actual transaction price, and 0 otherwise.

by local governments, which reveals a clear negative relationship between the size of subsidies and spillovers (see Figure 6 Panel (b)).

[Table 6 about here]

Robustness We conduct three falsification tests to further verify the validity of the DID identification. First, we examine the parallel-trend assumption by regressing land value on the leads and lags of the skyscraper entry year dummy and ring indicators with the same controls as in Equation (3). Figure 7 Panel (a) presents the event study results. As shown, there is no clear pre-trend in the outcome (the value of land near a skyscraper in the years leading up to the announcement of its construction).[23] Land prices start to appreciate only after the construction is finished. However, the positive effects appear to diminish and do not persist in the long run, as indicated by the estimates of event years 4 and 5 (plus).

[Figure 7 about here]

Second, one might worry that the local supply of land, dominated by the local government might respond to skyscraper development in a concerted effort to boost local agglomeration. Thus we further explore whether there was a sharp change in the quantity or quality (measured as the distance to the CBD, transfer mode and land grade level) of land sale transactions after the skyscraper was completed to rule out a supply-side effect. The estimation results, reported in Table A5, indicate that the completion of skyscrapers has no impact on either the quantity or quality of the newly supplied land parcels nearby.

Third, we employ a spatial randomization inference test to demonstrate that the baseline results are not spurious due to a mis-specified empirical model. We construct a counterfactual location selected at random from within 5km of a skyscraper, while keeping the year of construction unchanged. We re-estimate the main coefficient of interest (the coefficient

[23]On average, skyscrapers are completed less than 4 years after their construction is announced (source: https://www.skyscrapercenter.com/country/china/buildings.)

on the interaction term "0-1km * Post") using the baseline specification. To increase the statistical power of the randomization test, we repeated this procedure 2,000 times. Figure A3 illustrates the density distribution of point estimates from 2,000 runs. The red line, which presents the benchmark estimate of 0.648, lies outside the 99% confidence interval of those placebo estimates. The results suggest that spillovers occurred only in the observed skyscraper areas, not in the neighborhood of the counterfactual sites. The p-value (0.02) rejects the possibility that a mis-specified empirical model is driving the results for skyscraper spillovers.

Alternative Outcomes We have thus far presented evidence of skyscrapers' spillover effects on land value in surrounding areas. Although the regressions included a rich set of observable parcel characteristics, it is unclear to what extent the transaction price of land reflects its true market value in China given the complex situation of urban state-owned land use rights. To address this issue, we directly examine the impact of skyscraper entry on surrounding economic activities. We collect data on annual firm registration records (2003–2015) and commercial POI (2010–2017), which include 15.4 million and 10.8 million observations, respectively.[24] Locations of firms and local business amenities were then geo-coded. We created a balanced panel of 1km × 1km grid-cells of the number of newly established firms and local business amenities and employed the following empirical specification:

$$\ln\left(Y_{ijt}\right) = \alpha_{jt}^{Y} + \lambda_{i}^{Y} + \left(\beta_{1}^{Y} D_{ij}^{1} + \theta_{1}^{Y} D_{ij}^{2}\right) * \text{Post}_{ijt} + \varepsilon_{ijt}^{Y} \tag{4}$$

where Y_{ijt} is the log of outcomes of interest in grid-cell i in year t near skyscraper j. α_{jt} is a skyscraper-matched-sample j-year t fixed effect, and λ_i is a grid-cell i fixed effect. D_{ij}^1, D_{ij}^2 are indicator variables of grid-cell i located $0-1$ or $1-2$km from skyscraper j. The $2.5-3.5$km

[24]The firm registration data were obtained from the State Administration for Industry and Commerce, while the POI data were sourced from Gaode Map API (https://lbs.amap.com/).

ring serves as the control group. ε_{ijt}^{Y} is the error term. Table 7 reports the estimation results. Column (1) indicates that a skyscraper increases the number of newly registered services firms by 59% ($e^{0.461} - 1$) within a 1km radius, while the spillovers on areas 1–2km from the skyscraper decay considerably and the estimates become less significant. Figure 7 Panel (b) also presents event-study results on how skyscraper construction has affected service firm agglomeration. Reassuringly, the dynamic pattern is similar to those observed for the land premium. In columns (2) and (3), we classify service sector firms into high- and low-end types and repeat the spatial DID regression exercises. The estimates suggest that while skyscrapers attracted relatively large numbers of low-end service firms, their effects on boosting the agglomeration of the high-value-added industry are much lower in magnitude. Column (4) uses the full sample of service sector firms and further interacts the two treatment indicators with an indicator variable of whether or not the skyscraper received a discounted land price $Subsidy_j$. The estimates indicate that the spillovers of subsidized skyscrapers on services firm registration is 0.359 (i.e., 0.531-0.172) and are not statistically significant. Columns (5) and (6) illustrate that skyscrapers have not affected the agglomeration of manufacturing sector firms. Reassuringly, column (7) indicates that these high-rise buildings generate very local spillovers on local business amenities. Column (8) again confirms the absence of positive externalities from subsidized skyscrapers. Finally, we obtain alternative DID estimators following the method of De Chaisemartin and d'Haultfoeuille (2020), which addresses the negative weight issue that results from the staggered rollout of skyscrapers. The results are robust to various methods of estimating the effect (see Table A6). Taken together, the skyscraper's spillover impacts on service sector firms and other commercial facility establishments deliver fairly consistent magnitudes and spatial patterns. These additional results lend further credibility to our baseline results.

[Table 7 about here]

5 Interpretation and Discussion

5.1 Potential Channels

The main finding of skyscraper spillovers indicates that subsidizing their construction has *not* achieved local governments' intended objective of fostering new urban agglomerates. We now propose and evaluate evidence of two plausible reasons for this failure. First, the magnitude of the spatial spillovers is strongly associated with a skyscraper's location, which was mainly determined by the local government. Recall the results in columns (2)–(3) of Table 5: larger subsidies were granted to motivate developers to locate their projects in smaller cities and new towns away from the CBD. Naturally, these sites have lower urban density than the CBD and likely worse transport accessibility, which makes it harder for them to attract new businesses. Thus in general, the sites selected to build skyscrapers on were not well grounded economically.

Second, the lack of spillovers could be driven by worse skyscraper development progress. There is considerable anecdotal evidence of state-initiated new CBD that failed to deliver due to the slow or unsatisfactory development of the central skyscraper project. An example is the Wuhan Wangjiadun CBD: planning started in 2001 and construction commenced in 2006. However, the main developer of multiple high-rises central to this initiative, Oceanwide, was slow to develop because it was overwhelmed by multiple skyscraper projects globally and exposed to capital chain rupture.[25] The project still has not generated the expected spillovers.

Subsidies could worsen the principal–agent problem between local governments and commercial real estate developers. On the one hand, discounted land prices magnify the adverse selection issue, and attract less experienced and financially unstable developers. On the other hand, there could be an *ex post* moral hazard problem: the winning bidder of a

[25] Source: https://www.bloomberg.com/news/articles/2021-10-29/chinese-developer.

skyscraper project might not have strong incentives to maximize efficiency after they receive the subsidies and other implicit support from the local government. To test these two channels, we collect comprehensive financial data from the China National Tax Survey Database (2006–2015)—including return on assets, return on equity, and debt-to-assets ratio—for 65 skyscraper developers. Columns (1) to (3) of Table 8 test the bivariate relationship between the subsidy received (measured by the land price discount) and the developer's quality (proxied by their past financial performance). We find no significant associations between the land price discount and developers' profitability in columns (1) and (2). However, column (3) indicates that subsidized developers on average had a much higher leverage ratio before construction started. In column (4), we also observe that subsidized skyscrapers tend to take significantly longer to build than their non-subsidized counterparts, which could be driven by both the adverse selection and moral hazard channels. These results suggest that subsidized skyscrapers tend to be built by developers with a higher risk of capital chain rupture, and take longer to construct.

[Table 8 about here]

Link Potential Channels to Skyscraper Spillovers We then test whether the aforementioned characteristics of subsidized skyscrapers explain the lack of spillovers. We augment the analysis in Section 4 by interacting skyscraper entry with skyscraper characteristics including locational fundamentals and developer quality. The results are presented in Table 9. Columns (1) and (2) interact $D^1_{ij} * \text{Post}$ and $D^2_{ij} * \text{Post}$ with city size and distance from the CBD. The estimate of $D^1_{ij} * \text{Post} * CitySize$ shows that the spillover effect does not significantly differ across mega-cities and smaller cities. However, the result in column (2) confirms that skyscrapers located in new towns far from the city center generate fewer positive spillover effects. In columns (3) and (4), we interact the treatment indicators with the project construction duration and developer's leverage ratio. Lower development efficiency is found to significantly inhibit skyscrapers' neighborhood agglomeration economies.

Meanwhile, developer leverage is associated with significantly fewer spillovers. Taken together, Table 9 verifies that intra-city location choice, *ex ante* developer quality, and *ex post* developing efficiency are the three channels driving the economic impacts of skyscrapers.

[Table 9 about here]

5.2 City-wide Analysis

Some scholars are generally skeptical of state-led urbanization initiatives. It is unclear whether such public investments stimulate real growth or merely reshuffle economic activities across different areas. Still, for many development practitioners in developing countries, the potential to generate long-term, city-wide benefits constitutes a strong argument in favor of government interventions to promote skyscraper construction.

To identify the broader impacts of skyscrapers, we collected city-level panel data between 2003 and 2015 on land prices and new establishments. Following the lead of Albouy et al. (2018), we estimate the land price index at the city center to ensure the measure is comparable across time and regions. For new establishments, we aggregate the firm registration records to the city-year level. We exclude cities that had constructed skyscrapers before 2003 from our sample and use those that built their first skyscraper after 2015 as the control group. In a DID design, we then compare a city's land value and the number of new establishments before and after the skyscraper were built using the following specification:

$$\ln(Y_{it}) = \alpha_t^C + \lambda_i^C + \beta_1^C Skyscraper_{it} + \varepsilon_{it}^C \tag{5}$$

where the dependent variable, Y_{it}, denotes city i's land value index and firm registration in year t. α_t^C are year fixed effects, which capture common macro-level shocks that affect all cities. λ_i^C are city fixed effects that account for unobserved time-invariant differences across cities that may affect the outcomes. *Skyscraper* denotes the log number of skyscrapers. Its coefficient β_1^C is the parameter of interest to be estimated, which indicates the city-wide economic impact of building more skyscrapers. ε^C_{it} is the error term.

Columns (1) and (5) of Table 10 present the baseline estimates using Equation (5). Columns (2) and (6) add a set of additional socio-demographic variables including log city employment, the share of residents with a university degree, and road density. The results are robust to these controls. In columns (3) and (7), we replace the continuous treatment intensity indicator with a dummy variable that equals 1 after the city has built its first skyscraper, and 0 otherwise. As shown, the estimates are not sensitive to how the treatment indicator is defined. To further address the negative weights issue with staggered DID, columns (4) and (8) present the alternative Wald-DID estimators. The coefficients with different specifications are generally positive and insignificant, which suggests a weak relationship between skyscraper construction and city-wide economic growth. The event studies in Figure 7 Panels (c) and (d) again display consistent evidence that skyscrapers did not confer short- or long-term benefits on wider regions.

[Table 10 about here]

5.3 An Illustrative Welfare Analysis

The previous analyses focused on understanding the determinants of vertical structures and identifying their economic externalities in China. In this section we explore the welfare consequences of encouraging skyscraper development. To gauge the magnitude of their aggregate impacts, we perform back-of-the-envelope calculations using the estimated parameters as an illustrative exercise.

The parties that would benefit from skyscraper projects include developers, renters, local governments and external beneficiaries through spillovers. For simplicity, we assume zero profit for developers after subsidies, and the renters' productivity advantages through within-building agglomeration are exactly offset by higher rents.

The benefits that accrue to local governments mainly come from land price appreciation of nearby parcels, which translates into higher direct land revenue and land transaction-related tax revenue. For the tax revenue, we we account for deed tax (0.05% of the transaction price), stamp tax (0.05% of the transaction price), and land use tax ($18-30RMB/m^2$). It is noted that the estimated coefficients on land price spillovers from subsidized skyscrapers are statistically insignificant, as shown in Table 6. Therefore, in this calculation, our estimate of the nearby land price appreciation ranges from zero to the exact estimated coefficient obtained from Table 6, which we consider to be an upper bound.

Based on the parametric estimates of premium effects ($\widehat{\beta_1^P}$, $\widehat{\theta_1^P}$), the counterfactual total value of affected land parcels near a skyscraper, $\tilde{\pi}^{\text{land}}$, is calculated as: $\sum_{n=1}^{N} \frac{\pi_n^{\text{land,0-1km}}}{\left(1+\widehat{\beta_1^P}\right)} + \sum_{m=1}^{M} \frac{\pi_m^{\text{land,1-2km}}}{\left(1+\widehat{\theta_1^P}\right)}$. Hence, the land value appreciation due to skyscraper construction can be written as the total difference between the actual and counterfactual values ($\pi^{\text{land}} - \tilde{\pi}^{\text{land}}$).

As for the potential costs and benefits accrued to external beneficiaries through spillovers, it is arguable that they will be capitalized into land value appreciation, which has been partially counted in the previous estimate. However, our calculation only accounts for land value appreciation on newly transacted parcels, but not parcels transacted in the past, as our land transaction data is limited to the primary market. Therefore, the above calculation effectively assumes that the land value appreciation from past land transactions near subsidized skyscrapers is zero.[26]

We now consider the costs to various parties. Under the zero-profit assumptions of developers, we focus on the costs incurred to the government. Subsidies (particularly the heavy discount for skyscraper land purchase) account for a substantial share of local governments' costs. We estimate the cost of the subsidy in the form of the land price discount as the

[26]This assumption is consistent with the insignificant estimated spillover effects that subsidized skyscrapers have on land transaction value in the primary market, as well as on the number of newly registered firms and business amenities reported in Table 7. Alternatively, our welfare calculation could be interpreted more narrowly as the net gain in local government's revenue, which omits potential land/housing price appreciation accrued to the private sectors.

difference between the transaction price of the land parcel for skyscraper construction (r^{land}) and the land's counterfactual market price. Thus, the land discount granted to a representative skyscraper can be calculated using the following formula: $\tilde{r}^{\text{land}} = r^{\text{land}} / \left(1 - \widehat{\beta_1^D}\right)$. Note that the discount rate β_1^D was previously quantified using Equation (2). We also consider the tax loss due to the land price discount as a minor part of the costs.

Table 11 reports the results of these back-of-the-envelope calculations. The benefits yielded are shown in Panel A and the costs incurred are shown in Panel B. In column (1), the average price of land parcels sold after skyscraper construction is 11102.6 RMB per square meter. Column (2) displays the previously estimated parameters from Equation (3). Column (3) suggests that the unit land price appreciation linked to skyscraper construction is 2428.7 RMB during our study period. We have also utilized the fact that the premium effect is concentrated within the 1km radius of skyscrapers. Columns (4) and (5) thus present the characteristics of land parcels sold by local governments in the 0–1km ring around subsidized skyscrapers after construction. On average, two land parcels were sold between the year that skyscraper construction completed and 2015, the last year in our sample,[27] with an average lot size of 2.9 hectares. Column (6) presents the change in land transaction-related tax revenue. Combining columns (3) to (6), the total increase in the land value of parcels around a representative skyscraper and tax revenue is approximately 141 million RMB, as reported in column (7).

In a similar vein, we compute the costs associated with skyscraper projects. The average transaction price of land parcels for skyscraper construction is 5062.5 RMB per square meter and the average size is 3.2 hectares. Using the previously estimated discount rate $-\beta_1^D$ of 52%, we calculate that a skyscraper's land price discount and tax loss are around 175.7 million RMB. A comparison of premium benefits and subsidy costs reveals that a skyscraper, on

[27]On average, the duration between the skyscraper completion year and 2015 is four years in our sample. The supply of land around subsidized skyscrapers is limited and the average number of transacted land parcels barely changed over the post-completion period.

average, yields an estimated net loss of 34.7 million RMB (or 5.1 million USD). If the land appreciation takes the conservative estimate of zero, the average net loss of a subsidized skyscraper project would be approximately 175 million RMB.

[Table 11 about here]

6 Conclusion

The rapid build-up of skyscrapers in multiple Chinese cities during 2006–2012 presents a unique opportunity to evaluate the pattern of skyscraper development in a developing country. We document a novel set of stylized facts, which show that skyscrapers in developing countries are less responsive to economic fundamentals. We find that the height gradient of Chinese skyscrapers is much flatter than that of their American counterparts, which represents a clear deviation from the land–capital substitution theory. The elasticity of skyscraper height with respect to land price is also much smaller in China, likely due to factors outside the competitive market framework.

We then look for plausible explanations for these stylized facts. We examine whether government intervention was the force underpinning China's skyscraper development and empirically quantify this involvement. We find that local governments granted sizable subsidies to skyscraper projects, mainly in the form of price discounts on land for construction. More discounts were provided for projects in small cities, suburban districts and those led by younger leaders. We demonstrate that these discounts are negatively associated with height elasticity.

Finally, we evaluate the policy rationales behind government intervention in skyscraper development: local officials encourage high-rise commercial buildings to boost urban growth in their jurisdictions and to increase their chances of promotion. We then evaluate the economic impacts of skyscrapers. We detect a very localized spillover effect. Moreover, we find that the larger the subsidies provided, the smaller the positive spillovers are. Our illuminating back-of-the-envelope calculation suggests that skyscrapers are associated with a net loss, especially for heavily subsidized projects. These findings indicate that the state-led urbanization drive is not economically beneficial, and highlight considerable resource misallocation in China's land market.

While our paper has taken an important step towards understanding the causes and consequences of Chinese skyscrapers, much remains to be done. Data limitations prevented us from investigating longer-term returns to the skyscraper projects. Arguably, agglomerative clusters are slow to develop, and an evaluation of the potential of skyscrapers in anchoring new subcenters in the long run could be an interesting avenue for future research.

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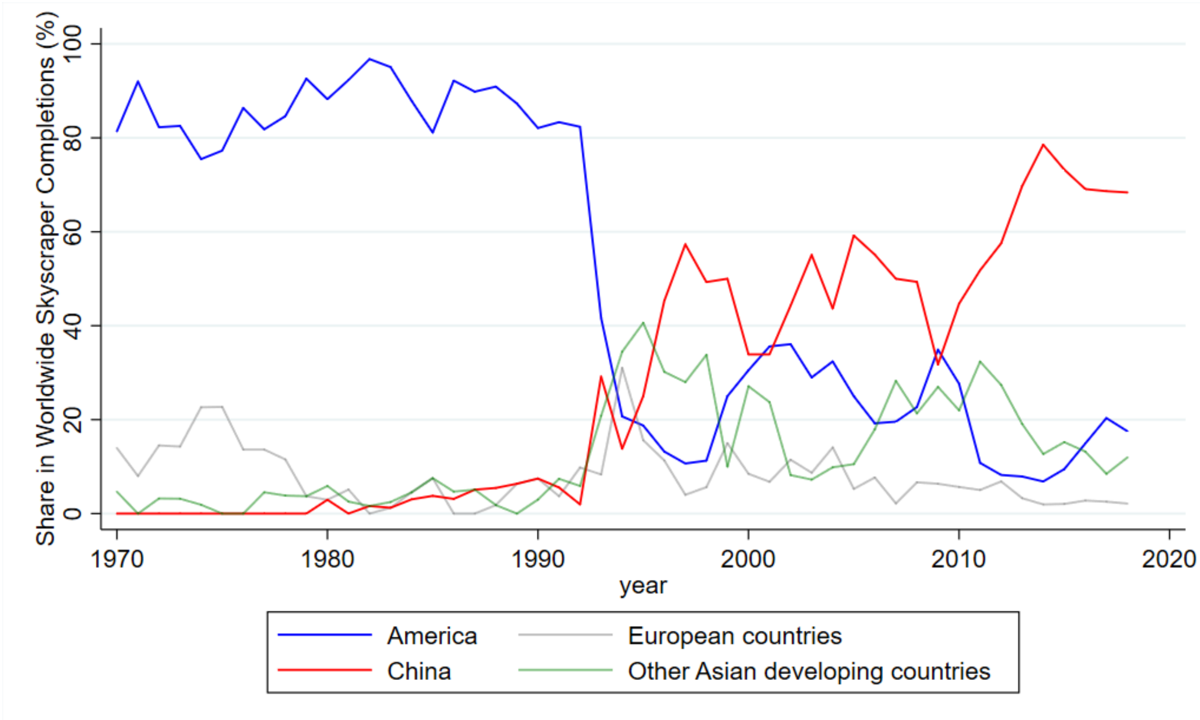


Figure 1: Trend of Worldwide Skyscraper Completions

Note: Using data extracted from the Global Tall Building Database of the CTBUH, this figure presents the evolution of annual skyscraper completions in America, European countries (Belgium, France, Germany, Italy, Netherlands, Poland, and Spain), China, and other Asian developing economies (India, Indonesia, Kuwait, Malaysia, Philippine, Qatar, Thailand, United Arab Emirates, and Vietnam). A skyscraper is defined as a high-rise commercial building over 100m high, according to the "Uniform Standard for Design of Civil Buildings: GB 50352-2019" issued by China's Ministry of Housing and Urban–Rural Development.

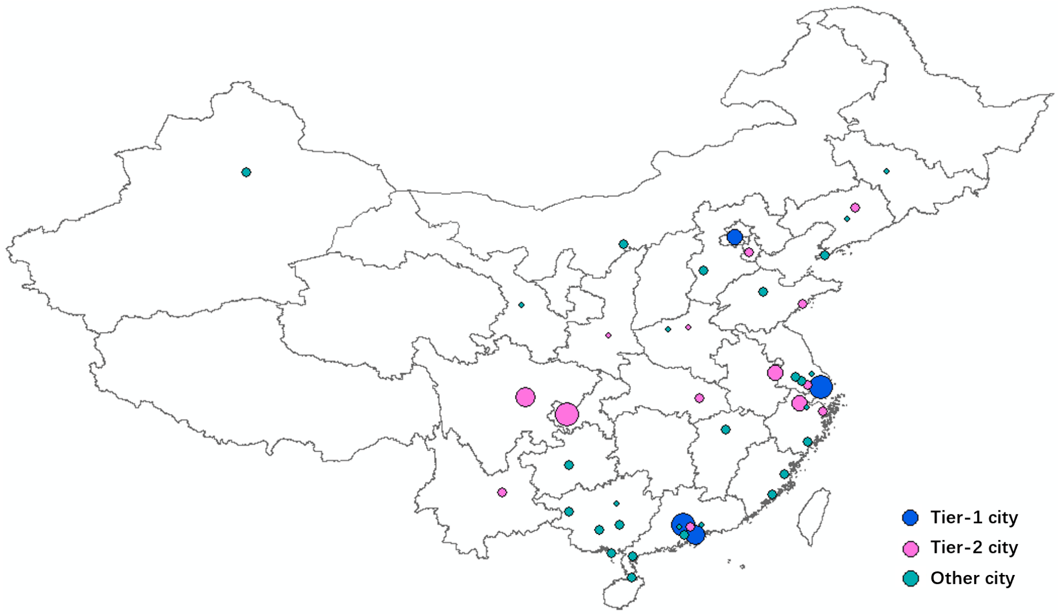


Figure 2: Geographic Distribution of Newly Completed Skyscrapers in China, 2006–2012

Note: Circles indicate skyscraper cities, and their size is proportional to the number of skyscrapers built. The color illustrates which tier these cities belong to.

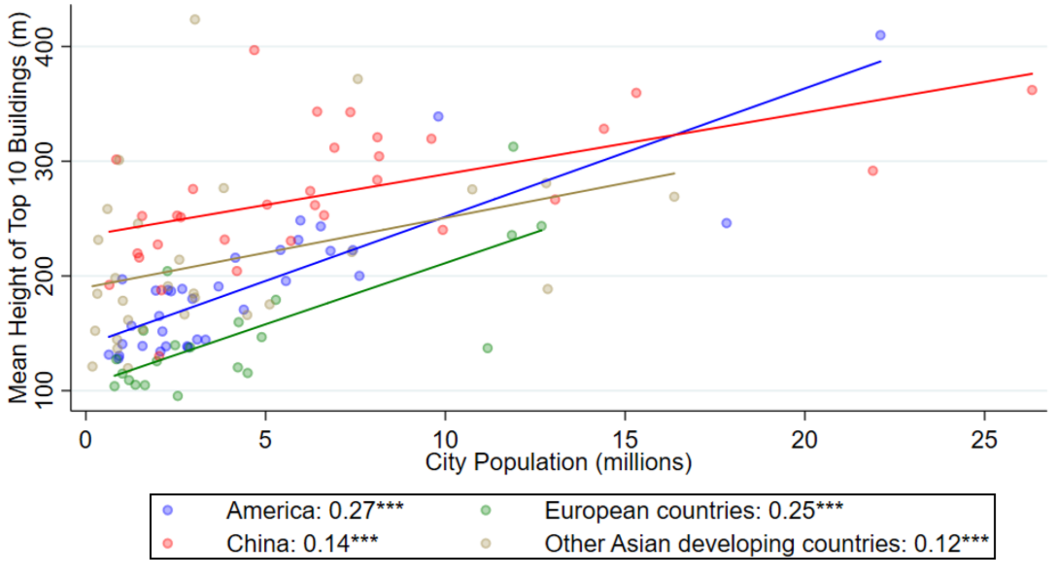


Figure 3: Skyscraper Heights and City Population: An International Comparison, 2018

Note: This figure displays the raw relationship between a city's (metropolitan) population and the average height of its 10 tallest buildings in four sets of regions. The sample includes cities that host more than 10 skyscrapers and are located in America (34 cities), European countries (21), China (32) and other Asian developing countries (30). The legend includes the estimated population elasticities of building height for the four regions. * significant at 10%; ** significant at 5%; *** significant at 1%.

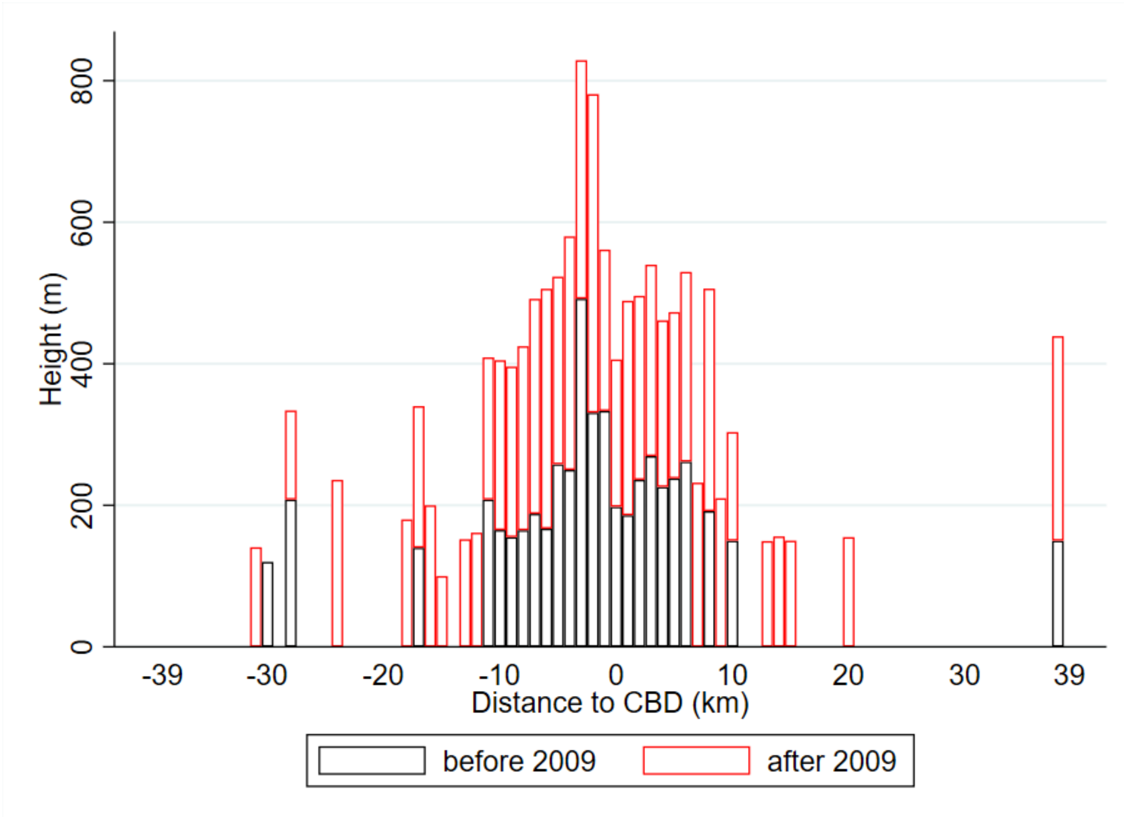


Figure 4: Distribution of Tallest Buildings by Distance from the CBD across Chinese Cities, 2006–2012

Note: Each bar represents the tallest building within a 1km bin to the west or east of the CBD across Chinese skyscraper cities before and after the nationwide 2009 economic stimulus plan. The data on heights were obtained from the Global Tall Building Database of the CTBUH. Negative (positive) distance values indicate a location in the west (east) where the skyscraper's x-coordinate in the World Mercator projection is smaller (larger) than the x-coordinate of the CBD.

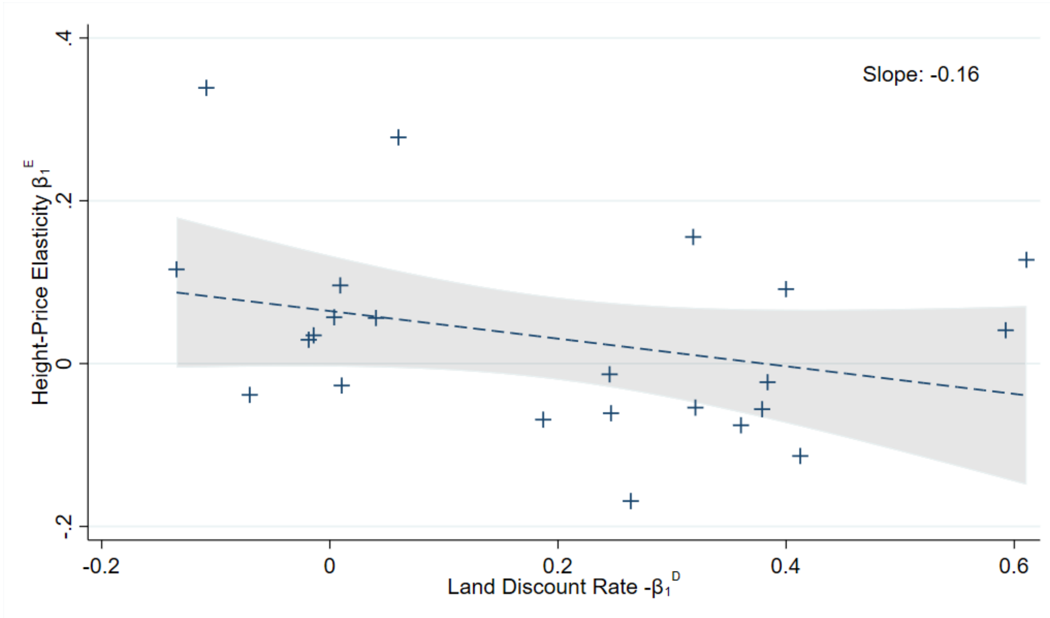
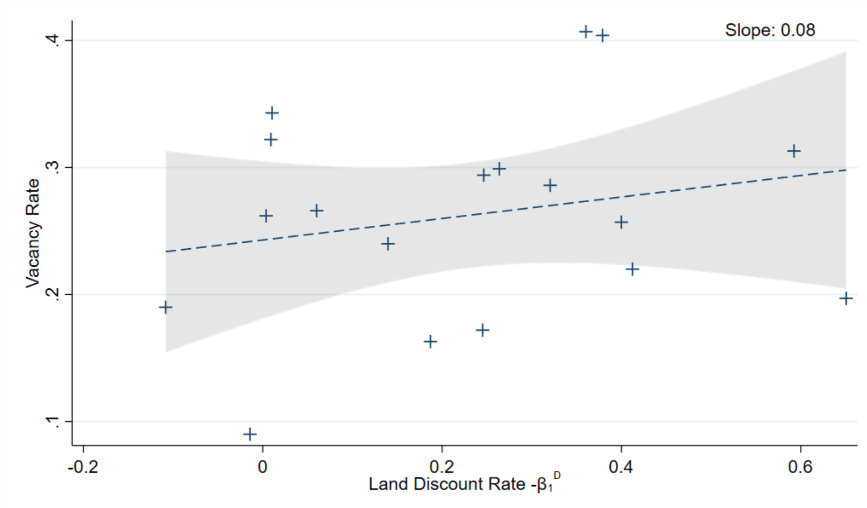
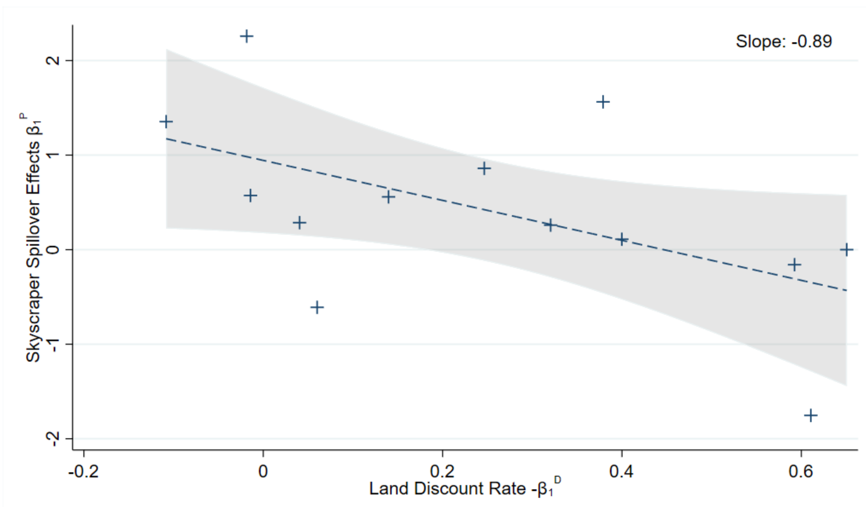


Figure 5: Correlation between Land Price Discount Rate and Region-Specific Height–Price Elasticity

Note: This figure plots raw correlations between the land price discount rate and height–price elasticity. To increase the statistical power, we combined the 42 cities into 26 regions according to city size and geographic proximity. The vertical axis represents the region-specific elasticity of building height with respect to land price (β_1^E), which is estimated based on Equation (1). The horizontal axis represents the land discount rate ($-\beta_1^D$) estimated from Equation (2). The dashed line shows the best linear fit estimated on the underlying region-level data and the slope is -0.16. Shaded areas depict 95% confidence intervals.



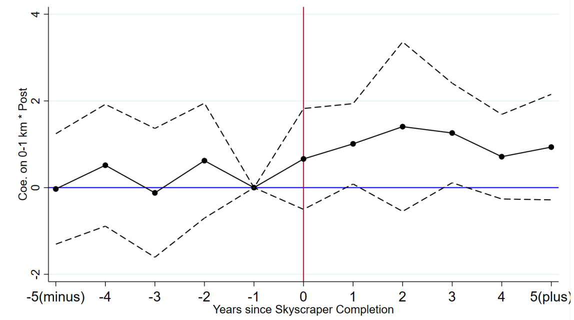
(a) Correlation between Land Discount Rate and Region-Specific Vacancy Rate



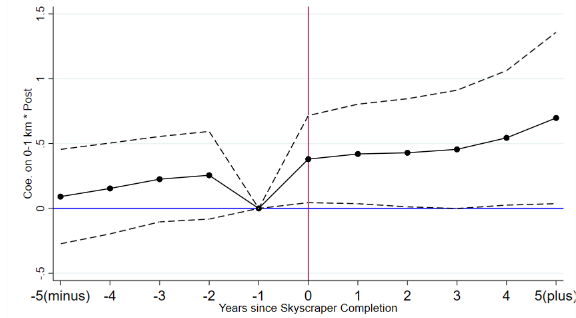
(b) Correlation between Land Discount Rate and Region-Specific Skyscraper Spillovers

Figure 6: Economic Returns of Skyscrapers

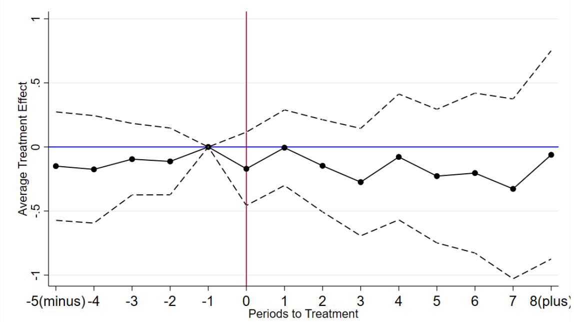
Note: Panel (a) plots raw correlations between the land price discount rate and office vacancy rate. The horizontal axis represents land discount rate ($-\beta_1^D$). The vertical axis represents the average vacancy rate in the regional grade-A office market, which is sourced from the "Greater China Top Office Supply/Demand Trend" (Cushman & Wakefield, 2020). The dashed line shows the best linear fit estimated on the underlying region-level data, and its slope is 0.08. Panel (b) plots raw correlations between the land price discount rate and spillovers generated by skyscrapers in a set of regions. The horizontal axis represents the land discount rate ($-\beta_1^D$). The vertical axis represents the spillover effects of a skyscraper on the land value within a 1km radius (β_1^P), estimated from Equation (3). The dashed line shows the best linear fit estimated on the underlying region-level data, and its slope is -0.89. Shaded areas depict 95% confidence intervals.



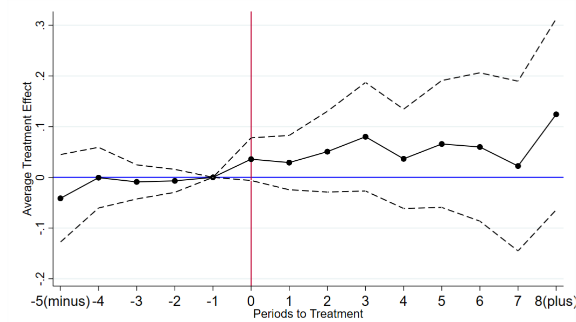
(a) Land Value (neighborhood)



(b) Firm Registration (neighborhood)



(c) Land Value (city-wide)



(d) Firm Registration (city-wide)

Figure 7: Event Study of Skyscrapers' Neighborhood Spillovers and City-wide Impacts

Note: Panels (a) and (b) report estimates of a skyscraper's dynamic spillover effects on land value and firm registration obtained from a flexible DID specification. Pre-treatment data for 9 years leading up to the completion of skyscrapers and post-treatment data up to 9 years afterwards are used. Note that due to sample size limitations, parcels transacted 5–9 years after the skyscraper's completion are categorized as the event window "5 (plus)," and those transacted 5–9 years prior to completion are categorized as the event window "5 (minus)." A series of $\beta^P_{1,t}s$ and $\beta^Y_{1,t}s$ are estimated for the 11-year event window based on Equation (3) and (4), respectively. The omitted category $t = -1$ is the year prior to the skyscraper's completion, so $\beta^P_{1,-1} = 0$ and $\beta^Y_{1,-1} = 0$.
Panels (c) and (d) report estimates of the dynamic effects of skyscraper construction on city-wide land value and firm registration derived from a flexible DID specification. Pre-treatment data for 9 years leading up to the completion of skyscrapers and the post-treatment data up to 12 years afterwards are used. Observations 8–12 years after completion are categorized as the event window "8 (plus)," and those 5–9 years beforehand are categorized into the event window "5 (minus)." A series of $\sum_{t=-5,t\neq-1}^{8} \beta^Y_{1,t}s$ are estimated for each year within the 14-year event window, based on Equation (5). The omitted category $t = -1$ is the year prior to the skyscraper's completion, so $\beta^C_{1,-1} = 0$. The dashed lines plot the 95% confidence interval for the estimates.

Table 1: Descriptive Statistics of the Land Parcel Sample, 2003–2015

	Skyscraper land	Non-skyscraper land	Difference
	(1)	(2)	(3)
Land price (RMB/m^2)	4025.5	5575.1	-1549.6**
	(634.5)	(163.8)	(730.1)
Land grade (1-15)	4	4	0
	(0.2)	(0.1)	(0.2)
Land area (hectare)	5.2	4.8	0.4
	(1.3)	(0.3)	(1.2)
Distance from the city center (km)	6.5	7.0	-0.5
	(0.6)	(0.1)	(0.6)
Number of transactions	120	2,299	

Note: This table summarizes the descriptive statistics of the land parcel sample. Land price is the unit price per square meter. Land grade represents the land quality under China's 15-grade classification (1–15). Land area denotes the area of the parcel. Distance from the city center measures the Euclidean distance between the land parcel and the CBD. Standard errors of the mean (SEM) are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: Land Price Elasticity of Height: China versus the US

	Summary of estimated height–price elasticities (β_1^E)			
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Panel A: Chinese skyscraper cities				
	0.010	0.073**	0.069***	0.165**
Instruments				
Distance to CBD	No	Yes	No	Yes
Distance to amenities	No	Yes	No	Yes
Weak identification statistic	-	30.8	-	6.4
R^2	0.071	-	0.206	-
Panel B: US (Chicago)				
	0.202***	0.188***	0.102**	0.169***
Instruments				
Distance to CBD	No	Yes	No	Yes
Distance to Lake Michigan	No	Yes	No	Yes
Weak identification statistic	-	12.3	-	12.3
R^2	0.46	-	0.46	-
Building type	Commercial	Commercial	Residential	Residential

Note: This table reports the estimated land price elasticity of building height in 2010 from OLS and IV regressions. The China sample is composed of 517 tall buildings: 208 are skyscrapers (high-rise commercial buildings over 100m); the rest are high-rise residential buildings. All regressions control for the distance between the skyscraper and land parcels used in the skyscraper land value prediction to mitigate measurement error impact. The logarithm of the distance from the city's economic center and distance to the nearest amenities (public parks and train stations) are the instruments used for the endogenous land price variable. Cragg-Donald Wald F statistics are reported for weak identification tests. Robust standard errors are clustered at the city level. The US sample consists of 115 skyscrapers and 192 tall residential buildings in Chicago. The instruments utilized are the logarithm of the distance from the city's economic center and the logarithm of the distance from Lake Michigan. Kleibergen-Paap F statistics are reported for weak identification tests. Standard errors are clustered by construction date cohorts (decades). Columns (1)–(2) use skyscrapers. Columns (3)–(4) use tall residential buildings. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: Land Price Elasticity of Skyscraper Projects: Extensive Margin

Dep. Variable	Log # of buildings (grid cell level)				
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) Difference
Land value	0.009***	0.028***	0.020**	0.046***	0.018*
	(0.002)	(0.007)	(0.003)	(0.009)	(0.011)
Weak instrument statistic	-	12.8	-	6.95	
N	5,512	5,512	5,412	5,412	
R^2	0.041	-	0.108	-	
Instruments					
Distance to CBD	No	Yes	No	Yes	
Distance to amenities	No	Yes	No	Yes	
Building type	Commercial	Commercial	Residential	Residential	

Note: This table reports the estimated land price elasticity of building number from OLS and IV regressions. The dependent variable is the log of the number of buildings within a 1km $\times$ 1km grid cell. The independent variable, land value, is the cell average of the predicted land value. The independent variable, distance to the CBD, measures the distance between the city center and a cell. The logarithm of the distance from the city economic center, distance to the nearest public park/train station are the instruments used for the endogenous land price variable. Kleibergen-Paap F statistics are reported for weak identification tests. Robust standard errors are clustered at the city level. Columns (1)–(2) use skyscrapers. Columns (3)–(4) use tall residential buildings. The statistical difference between coefficients in columns (2) and (4) is calculated in column (5). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Average Land Price Discounts to Skyscrapers

Dep. Variable	Log land transaction price			
	(1)	(2)	(3)	(4)
Skyscraper land	-0.549**	-0.732**		
	(0.250)	(0.287)		
Tall residential building land			0.221***	0.116
			(0.0722)	(0.0727)
Matching	[$\leq 5km$]	[$\leq 2.5km$]	[$\leq 5km$]	[$\leq 2.5km$]
Matched pair FE	Yes	Yes	Yes	Yes
City by year FE	Yes	Yes	Yes	Yes
Parcel charac.	Yes	Yes	Yes	Yes
Amenity access	Yes	Yes	Yes	Yes
Spatial trend	Yes	Yes	Yes	Yes
Observations	2,014	681	2,717	965
R^2	0.694	0.838	0.560	0.589

Note: Using a spatially matched sample within a 5km radius of the skyscraper, column 1 reports coefficients from an OLS regression of land transaction price on a skyscraper land indicator and other control variables. Column 2 reports the OLS estimates using a sample within the 2.5km radius of the skyscraper. Columns 3–4 report coefficients from OLS regressions of land transaction price on a tall residential building land indicator and other covariates. The control variables include parcel characteristics (logarithm of the parcel size and its square, land grade, logarithm of the distance to the CBD), access to consumption amenities (logarithm of the distance to the nearest public park and educational facility), and spatial trend (latitude and longitude differences between the parcel and skyscraper × year trend). All regressions include matched-pair and city-year fixed effects. Robust standard errors clustered at the matched-pair level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Heterogeneous Land Price Discounts to Skyscrapers

Dep. Variable	Log land transaction price					
	(1)	(2)	(3)	(4)	(5)	(6)
Skyscraper land	-0.773**	-0.752	0.124	-1.114***	-0.0919	1.058
	(0.296)	(0.455)	(0.318)	(0.383)	(0.308)	(1.077)
Skyscraper land * Urban population		0.00346				0.00909
		(0.0395)				(0.0695)
Skyscraper land * Distance to CBD			-0.647**			-0.848***
			(0.255)			(0.177)
Skyscraper land * Mayor				-1.879*		-2.536**
				(1.089)		(1.179)
Skyscraper land * Secretary				0.621		0.495
				(0.508)		(0.402)
Skyscraper land * 4-trillion plan					-1.098**	-2.630***
					(0.542)	(0.520)
Matching	$[\leq 2.5km]$	$[\leq 2.5km]$	$[\leq 2.5km]$	$[\leq 2.5km]$	$[\leq 2.5km]$	$[\leq 2.5km]$
Matched pair FE	Yes	Yes	Yes	Yes	Yes	Yes
City by year FE	Yes	Yes	Yes	Yes	Yes	Yes
Parcel charac.	Yes	Yes	Yes	Yes	Yes	Yes
Amenity access	Yes	Yes	Yes	Yes	Yes	Yes
Observations	681	681	681	681	681	681
R^2	0.838	0.838	0.841	0.842	0.840	0.853

Note: Using a spatially matched sample within a 2.5km radius of the skyscraper, column (1) reports the coefficients from the baseline regression of land transaction price on a skyscraper land indicator along with parcel characteristics and amenity variables. Column (2) introduces an interaction term between the skyscraper land dummy and a measure of city population size in 2010. Column (3) interacts the skyscraper land dummy with a measure of the distance from the CBD. Column (4) interacts the skyscraper land dummy with measures of the municipal mayor's and party secretary's promotion incentives. Column (5) interacts the skyscraper land dummy with a measure of the "4 trillion economic stimulus plan." This measure equals 1 if the transaction took place after 2009 and in the city where commercial lending grew faster than the national average between 2007 and 2012. Column (6) includes those interaction terms together. All regressions include matched-pair and city-year fixed effects. Robust standard errors clustered at the matched-pair level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Economic Impacts of Skyscrapers: More Subsidies, More Spillovers?

Dep. Variable	Log land value			
	(1)	(2)	(3)	(4)
0-1km * Post	0.646**	0.648***	0.634***	1.040***
	(0.274)	(0.218)	(0.218)	(0.224)
1-2km * Post	0.149	0.222	0.232	0.448
	(0.266)	(0.250)	(0.244)	(0.286)
0-1km * Post * Subsidy				-0.790***
				(0.202)
1-2km * Post * Subsidy				0.008
				(0.201)
Control group	[2-3km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]
Skyscraper by year FE	Yes	Yes	Yes	Yes
Skyscraper-level clustering of SE	Yes	Yes	Yes	Yes
Parcel charac.	Yes	Yes	Yes	Yes
Amenity access	Yes	Yes	Yes	Yes
Spatial trend	No	No	Yes	Yes
Joint significance test				0.250
				(0.301)
Observations	955	1,011	1,011	873
R^2	0.845	0.850	0.852	0.842

Note: Using a spatially matched sample within a 3km radius of the skyscraper, column (1) reports the treatment coefficients on the two concentric rings (0–1km) and (1–2km); the 2–3km ring serves as the control. Column (2) uses an alternative sample within a 3.5km radius of the skyscraper, which excludes parcels in the 2–2.5km buffer ring. Column (3) further considers within-ring variation. Column (4) interacts the treatment indicators with a subsidy dummy (which denotes whether the skyscraper received any land price discounts). The control variables include parcel characteristics and access to consumption amenities. The extra controls include the spatial trend as defined in Table 4. All regressions include skyscraper-year fixed effects. Standard errors are clustered at the skyscraper level and reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: Economic Impacts of the Skyscraper: Alternative Outcomes

Dep. Variable	Log # of newly registered firms						Log # of business amenities	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0-1km * Post	0.461***	0.265***	0.424***	0.531***	0.185	0.281	0.205**	0.769***
	(0.142)	(0.0969)	(0.130)	(0.174)	(0.152)	(0.197)	(0.0875)	(0.162)
1-2km * Post	0.215**	0.133**	0.187**	0.473	0.149	0.121	0.119**	0.689***
	(0.0872)	(0.0627)	(0.0901)	(0.333)	(0.0928)	(0.120)	(0.0518)	(0.131)
0-1km * Post * Subsidy				-0.172		-0.165		-0.633***
				(0.248)		(0.233)		(0.146)
1-2km * Post * Subsidy				-0.211		-.0962		-0.654***
				(0.358)		(0.131)		(0.117)
sample mean	21	7	15	21	10	10	46	46
Firm/POI type		Service firms			Manufacturing firms		Commercial facilities	
Sample splitting	Full	High-end	Low-end	Full	Full	Full	Full	Full
Control group	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]
Skyscraper by year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Skyscraper-level clustering of SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Joint significance test								
0-1km marginal effect				0.359		0.116		0.136
				(0.303)		(0.305)		(0.218)
1-2km marginal effect				0.262		0.217		0.035
				(0.489)		(0.178)		(0.176)
Observations	20,891	20,891	20,891	14,062	14,129	7,841	21,671	16,387
R^2	0.900	0.867	0.903	0.901	0.852	0.852	0.796	0.756

Note: Using a spatially matched sample within a 3.5km radius of the skyscraper, all columns reports the treatment coefficients on the two concentric rings (0–1km) and (1–2km); the 2.5–3.5km ring serves as the control. Columns 1–4 use the sub-sample of service sector firms, columns 5–6 use the sub-sample of manufacturing sector firms, while columns 7–8 explore business amenity development before and after the skyscraper construction. Columns (2) and (3) further split service firms into high- and low-end firm groups, according to industry classification. Columns (4), (6), and (8) interact the treatment indicators with a subsidy dummy (which denotes whether the skyscraper received any land price discounts). Sample mean represents the mean number of local firms/business amenities in a grid cell. All regressions include grid and skyscraper-year fixed effects. Standard errors are clustered by skyscraper level and reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: Skyscraper Spillovers: Potential Channels

	Ex ante: developer quality			*Ex post*: developing efficiency
Dep. Variable	ROA	ROE	DTA	Construction duration
	(1)	(2)	(3)	(4)
Land discount rate	0.0834	0.0235	0.225***	0.261***
	(0.0974)	(0.0372)	(0.0650)	(0.0926)
Observations	49	49	49	80
R^2	0.009	0.005	0.168	0.082

Note: *Ex ante* developer financial position is measured by the mean return on assets (ROA), return on equity (ROE), and debt-to-assets ratio (DTA). Data are obtained from the China National Tax Survey Database (NTSD, 2006–2015). *Ex post* developing efficiency is measured as the construction duration of each skyscraper project. Column (4) uses the residual of the regression of construction duration on skyscraper characteristics (including height, construction mode, and land area) as the dependent variable. Robust standard errors are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 9: Link Potential Channels to Skyscraper Spillovers

Dep. Variable	Log land value			
	(1)	(2)	(3)	(4)
0-1 km * Post	0.964***	1.119***	0.812***	1.197***
	(0.289)	(0.228)	(0.195)	(0.385)
0-1 km * Post * City Size	-0.00109			
	(0.000778)			
0-1 km * Post * Distance to CBD		-0.440***		
		(0.0906)		
0-1 km * Post * **1**{Construction Duration above Mean}			-1.053***	
			(0.268)	
0-1 km * Post * **1**{Leverage Ratio above Mean}				-1.212**
				(0.461)
Control group	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]	[2.5-3.5km]
Skyscraper by year FE	Yes	Yes	Yes	Yes
Skyscraper-level clustering of SE	Yes	Yes	Yes	Yes
Parcel charac.	Yes	Yes	Yes	Yes
Amenity access	Yes	Yes	Yes	Yes
Observations	1011	1011	355	291
R^2	0.853	0.855	0.899	0.900

Note: All regressions are based on the specification used in Table 6, column (2). Column (1) interacts the treatment indicators with a measure of city population size in 2010. Column (2) interacts the treatment indicators with a measure of the distance from the CBD. Column (3) interacts the treatment indicators with a dummy which equals 1 if the predicted skyscraper construction duration (residual) is above the mean (0). Column (4) interacts the treatment indicators with a dummy which equals 1 if skyscrapers' *ex ante* leverage ratio is above the sample mean (0.73). Standard errors are clustered at the skyscraper level and reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 10: City-wide Impacts of the Skyscrapers

Dep. Variable	Land price index				Log # of firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log # of skyscrapers	0.00631	0.0530			0.0425	0.0281		
	(0.0986)	(0.106)			(0.0353)	(0.0304)		
Skyscraper city			0.0195	-0.020			0.0390	0.001
			(0.134)	(0.029)			(0.0332)	(0.002)
Method	TWFE	TWFE	TWFE	Wald-DID	TWFE	TWFE	TWFE	Wald-DID
City FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Time FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-
City controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	489	468	468	348	792	763	763	552
R^2	0.582	0.586	0.586	-	0.988	0.989	0.989	-

Note: This table reports the estimated city-wide impacts of skyscrapers. Columns 1–4 use the land price index (Albouy et al., 2018) as the dependent variable, while columns 5–8 use the logarithm of the number of new firms as the dependent variable. Columns 1–3 and 6–8 use a two-way fixed effect (TWFE) model. To mitigate concerns about heterogeneous treatment effects due to the staggered rollout of skyscrapers, columns (4) and (8) present the alternative Wald-DID estimators (De Chaisemartin and d'Haultfoeuille, 2020). Cities that had skyscrapers before 2003 are excluded from our sample, and cities that built their first skyscraper after 2015 are selected as the control group. City-level controls include employment, the share of residents with university degrees, and road density. Robust standard errors clustered at the city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 11: Cost and Benefit Analysis: A Back-of-the-Envelope Approach

	Actual unit price (RMB/m^2) (1)	Premium effect (2)	Counterfactual unit price (RMB/m^2) (3)	Parcel size (hectare) (4)	Parcel number (5)	Tax increase (million RMB) (6)	Benefits (tax-inclusive) (million RMB) (7)
Panel A. Benefits (land revenue)							
Overall	11102.6	0.28	8673.9	2.9	2	0.14	141.0
	Counterfactual unit price (RMB/m^2) (1)	**Discount rate (2)**	**Actual unit price (RMB/m^2) (3)**	**Parcel size (hectare) (4)**	**Parcel number (5)**	**Tax loss (million RMB) (6)**	**Costs (tax-inclusive) (million RMB) (7)**
Panel B. Costs (land discount)							
Overall	5062.5	0.52	10546.9	3.2	1	0.18	175.7

Note: This table reports the benefits and costs of a skyscraper project based on a back-of-the-envelope calculation. The benefits associated with skyscraper projects are shown in panel A, and the corresponding costs are shown in panel B. "Overall" denotes the sample of skyscrapers that received subsidies (land price discounts $-\beta_1^D$). Land premium gains and price discounts are further multiplied by transaction-related deed tax (0.05% transaction price), stamp tax (0.05% transaction price), and land use tax (18-30 RMB/m^2), yielding the estimates of benefits and costs.

Appendix

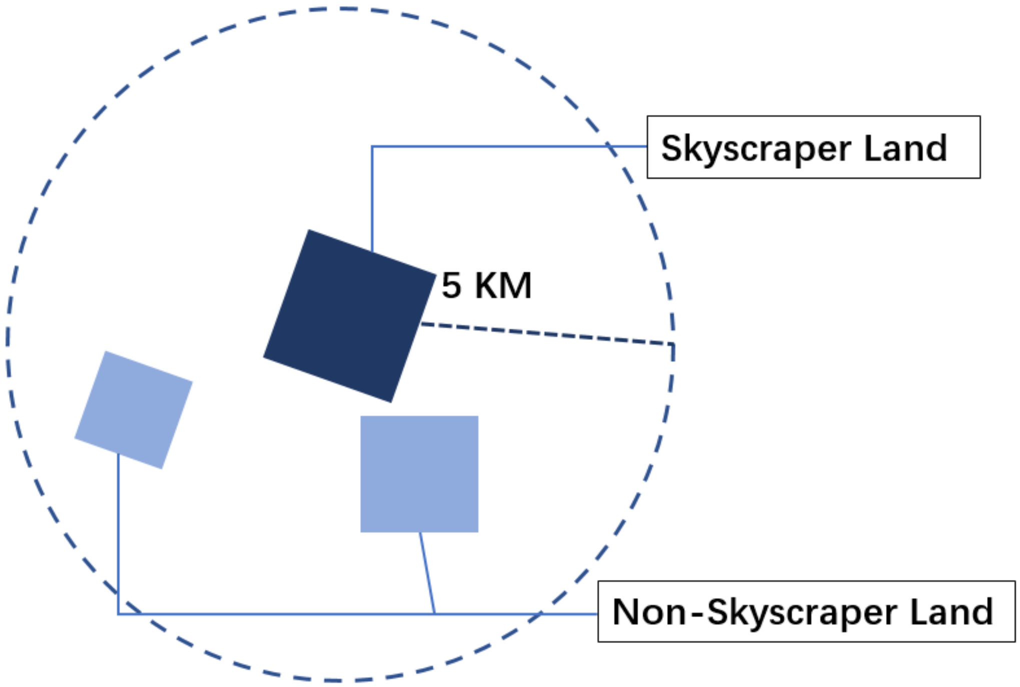


Figure A1: A Spatially Matched Sample for Quantifying Subsidies

Note: The figure displays a spatially matched sample of transactions involving skyscraper land (in dark blue) and non-skyscraper land (in light blue). To construct the sample, we chose transactions that took place prior to the skyscraper's construction. The geo-matching radius is initially set at 5km.

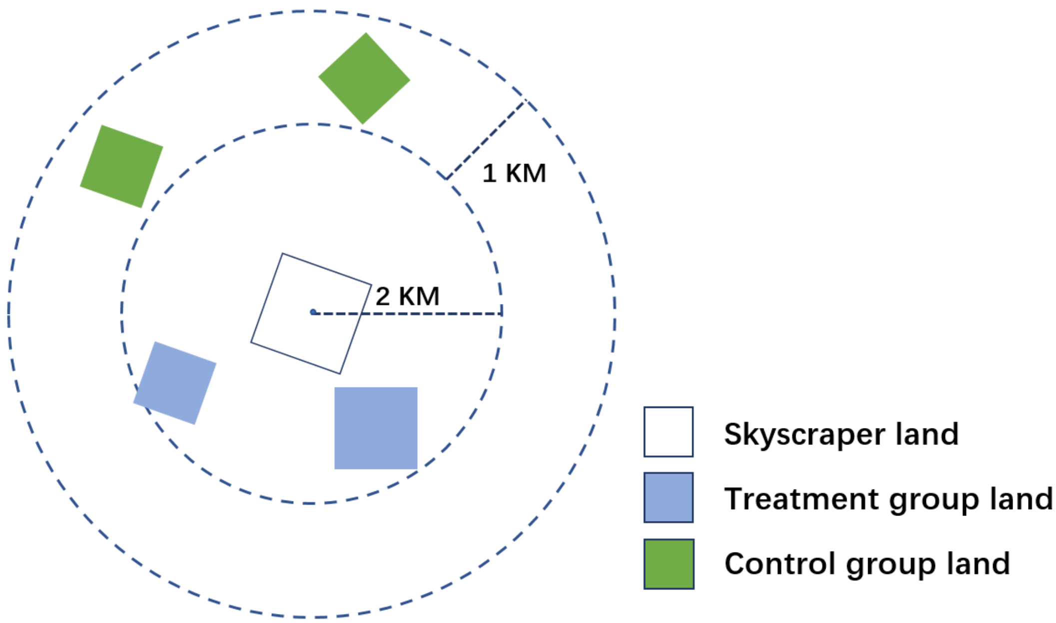


Figure A2: A Spatially Matched Sample for Identifying Spillovers

Note: The figure illustrates the method used to construct the sample to identify a skyscraper's spillover effects. Land parcels located within a 2km radius of a skyscraper are selected as the treatment group (in blue). Those located within the 2–3km ring (in green) are selected as the control group. The skyscraper land itself is excluded from the sample.

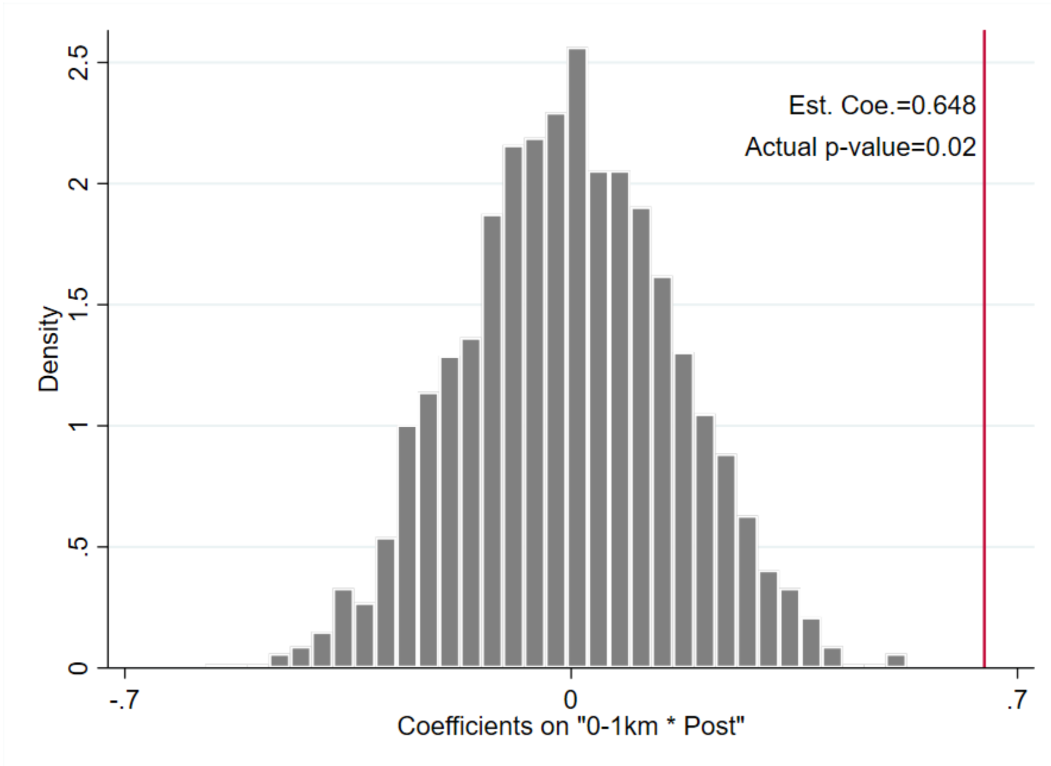


Figure A3: Spatial Randomization Test of Skyscraper Spillovers

Note: The figure shows the distribution of 2,000 coefficients from a spatial randomization test. The counterfactual locations were randomized within 0–5km of the true location. The red line is the baseline estimate and the exact p-value shows the likelihood of the original estimate being drawn from this distribution.

Table A1: A Cross-country Comparison of Height and Price Gradients

Dep. Variable	Log building height		Log land price	
	(1)	(2)	(3)	(4)
Log distance to CBD	-0.042**	-0.411**	-0.422***	-0.541***
	(0.021)	(0.162)	(0.049)	(0.005)
Sample	China	US (Chicago)	China	US (Chicago)
Observations	208	185	31,437	625,316
R^2	0.213	0.303	0.205	0.801

Note: Using 208 skyscrapers from China, column (1) estimates their height gradients by regressing the logarithm of the building height on the logarithm of the distance to the CBD. Column (2) reports the estimation of height gradients using data on 327 tall commercial buildings in Chicago. Columns (3) and (4) utilize land transaction records to estimate the price gradient for commercial land by regressing the logarithm of the land price on the logarithm of the distance to the CBD. Province and year fixed effects are included in columns (1) and (3). Robust standard errors clustered at the city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table A2: Relationship between Developer Background and Skyscraper Subsidy

Dep. Variable	Land discount rate	
	(1)	(2)
Local Real Estate Developer	-0.105	-0.123
	(0.213)	(0.205)
City Investment Group	0.264	0.302
	(0.220)	(0.274)
Foreign Capital	0.224	0.217
	(0.207)	(0.202)
Time FE	Yes	Yes
Building controls	No	Yes
Observations	53	53
R^2	0.105	0.128

Note: Using data on 53 Chinese skyscraper projects, for which accurate information on developers' background is available, column (1) reports the estimated relationship between the land discount magnitude and developer background. Developers are categorized into four groups with varying backgrounds: local real estate developers, city investment groups, foreign capital, and others (the reference group). Column (2) further includes building-level covariates. All regressions include time fixed effects. Robust standard errors in parentheses are reported. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table A3: Predicted Promotion Likelihood of City Leaders

Dep. Variable	Dummy: Promotion of city leader			
	Mayor (1)	Mayor (2)	Secretary (3)	Secretary (4)
Start age	-0.0213***	-0.0545***	-0.0227***	-0.0613***
	(0.00349)	(0.00924)	(0.00334)	(0.00915)
Dummy: Deputy-province	-1.475***	-4.001**	-0.629	-1.654
	(0.482)	(1.664)	(0.647)	(1.786)
Dummy: Province or above	-0.336	-0.648	-0.0935	0.219
	(0.921)	(2.675)	(0.549)	(1.795)
Start age * Dummy: Deputy-province	0.0254***	0.0684**	0.0119	0.0313
	(0.00934)	(0.0320)	(0.0130)	(0.0362)
Start age * Dummy: Province or above	0.00452	0.00690	0.00207	-0.00344
	(0.0176)	(0.0517)	(0.0101)	(0.0338)
Dummy: Graduate degree	-0.0423	-0.111	-0.0231	-0.0647
	(0.0320)	(0.0839)	(0.0322)	(0.0878)
Constant	1.494***	2.545***	1.507***	2.726***
	(0.169)	(0.446)	(0.171)	(0.463)
Summary statistics	Prediction of ex-ante likelihood of promotion			
1^{st} quartile	0.39	-0.28	0.30	-0.52
Median	0.45	-0.14	0.35	-0.40
3^{st} quartile	0.50	0.00036	0.42	-0.21
Observations	1,646	1,646	1,600	1,600
R^2	0.042		0.033	
Pseudo R^2		0.031		0.025

Notes: The table reports the predicted *ex ante* likelihood of mayor and secretary promotion from linear probability model and probit regressions. The city leader information is obtained from Jiang (2018), and we keep the data on 1,646 mayors and 1,600 secretaries who were in office between 2003 and 2015. Following Wang et al. (2020), we regress the promotion dummy on the leader's start age, the dummies of start levels (deputy, province or above, and omitted prefecture level), the interactions of start age and dummies of start levels with the leader's education attainment. These parameter estimates are used to predict ex-ante promotion likelihood for each mayor and secretary, and the prediction results are summarized and reported in the middle panel. Heteroskedasticity-robust standard errors in parentheses are clustered at the city level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table A4: Sorting Skyscrapers into Regional Groups

Regional Group	City 1	City 2	City 3
Group 1	Beijing		
Group 2	Tianjin		
Group 3	Shijiazhuang		
Group 4	Shenyang		
Group 5	Dalian	Changchun	Anshan
Group 6	Shanghai		
Group 7	Nanjing		
Group 8	Wuxi	Nantong	Changzhou
Group 9	Suzhou		
Group 10	Hangzhou		
Group 11	Shaoxing	Ningbo	Wenzhou
Group 12	Fuzhou	Quanzhou	
Group 13	Nanchang		
Group 14	Qingdao	Zibo	
Group 15	Xi'an	Luoyang	
Group 16	Wuhan		
Group 17	Guangzhou		
Group 18	Shenzhen		
Group 19	Foshan	Dongguan	Zhanjiang
Group 20	Nanning		
Group 21	Guigang	Baise	
Group 22	Haikou	Beihai	
Group 23	Chongqing		
Group 24	Chengdu		
Group 25	Kunming	Guiyang	
Group 26	Urumchi	Lanzhou	Ordos

Note: 42 skyscraper cities are combined into 26 regional groups, according to city size and geographic proximity.

Table A5: Falsification Test: Supply-Side Confounding Factors

Dep. Variables	Transaction volume	Distance from CBD	Parcel area	Transferring mode	Land grade
	(1)	(2)	(3)	(4)	(5)
0–1 km	-0.0883	-0.261	1.177	-0.0614	-0.0273
	(0.116)	(0.323)	(0.769)	(0.0388)	(0.530)
0–1 km * Post	0.0364	-0.260	-1.439	0.0432	-0.00976
	(0.147)	(0.319)	(1.020)	(0.0555)	(0.651)
1–2 km	-0.182**	0.0266	1.090	-0.0114	-0.265
	(0.0773)	(0.230)	(0.811)	(0.0342)	(0.343)
1–2 km * Post	-0.0961	-0.723**	-1.133	0.000278	-0.0222
	(0.133)	(0.311)	(0.856)	(0.0460)	(0.430)
Skyscraper by year FE	Yes	Yes	Yes	Yes	Yes
Skyscraper-level clustering of SE	Yes	Yes	Yes	Yes	Yes
Amenity	No	Yes	Yes	Yes	Yes
Spatial trend	No	Yes	Yes	Yes	Yes
Observations	440	1011	1011	1011	1011
R^2	0.595	0.995	0.316	0.597	0.815

Note: All columns are spatial DID regressions. The dependent variable in column (1) is the volume of land transactions (aggregated at the ring-by-year level). The dependent variables in columns (2)–(5) are parcel characteristics (distance from the CBD, parcel size, land grade and transferring mode, respectively), which are proxies for the quality of the supplied land. Statistically non-significant coefficients on "0–1km * Post" and "1–2km * Post" eliminate identification concerns about supply-side confounding factors. Standard errors are clustered at the skyscraper level and reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table A6: Economic Impacts of the Skyscraper: Alternative DID Estimators

Dep. Variables	Log # of newly registered firms	Log # of business amenities
	(1)	(2)
0-1km * Post	0.439**	0.364**
	(0.172)	(0.0.180)
1-2km * Post	0.104**	0.092
	(0.0405)	(0.0568)
Control group	[2.5-3.5km]	[2.5-3.5km]
Skyscraper by year FE	Yes	Yes
Skyscraper-level clustering of SE	Yes	Yes
Observations	20,891	21,671

Note: Using a spatially matched sample within a 3.5km radius of the skyscraper, all columns report the treatment coefficients on the two concentric rings (0–1km) and (1–2km); the (2.5–3.5km) ring serves as the control group. Column (1) uses the sample of service sector firms, and Column (2) explores business amenity development before and after skyscraper construction. To mitigate concerns about heterogeneous treatment effects caused by the staggered construction of skyscrapers, all columns present the alternative Wald-DID estimator (De Chaisemartin and d'Haultfoeuille, 2020). All regressions include grid and skyscraper-year fixed effects. Standard errors are clustered at the skyscraper level and reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.