The Hong Kong University of Science and Technology
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Programming Econometrics with R

An Empirical Study on Relationship between Skyscraper Height and Economic Development in Developing Countries

Final Project (option 1)[1] - 2023/24 Fall

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[1] Replicating the Result of "Skyscraper height and urban development in developing countries: economy and trade", Zhao, X., Mao, X. and Lu, Y. (2023)

Abstract

From Twin Tower in New York to IFC in Hong Kong, skyscrapers have always been the signature of a highly developed city, it is commonplace for international cities like Singapore, Shanghai and Tokyo to have a vast amount of skyscrapers while being economically strong. There are public options argue that whether skyscraper is a causal factor to the domestic economic growth or simply statistical corelated, and some even deem it as a “chicken and egg” problem. In this study, we examine factors influencing urban economic development in emerging economies and provides a new perspective on skyscraper construction with empirical approach. An empirical analysis using difference-in-differences (DID) modeling of 2003-2018 urban data from China during developed and emerging periods found skyscraper construction significantly positively impacted eastern city economies along with other aspects of the cities.

Keywords: Skyscrapers, Industrial agglomeration, Economic development

1. Introduction

The economic impacts of tall building development are being debated as urbanization speeds up worldwide. Since “Skyscraper index” was introduced by Andrew Lawrence in 1999 and further modified by Thornton, skyscrapers were deemed as a predictor of business cycle (Thornton, 2005), thus the impact of skyscrapers on economy was brought into the public slight. Although the relevant study has not been adopted in the academia field since it fails to offer a causal explanation, it still provides an idea that those things may impose some underlying relationship.

There exists some research with mixed results on how skyscrapers affect local economies, but the majority of the studies focus on developed markets. As emerging economies grow rapidly and expand their infrastructure, it's crucial to examine their experiences with vertical development on developing markets.

China provides an interesting case study, as it has transitioned rapidly from agriculture to industry to a service-led economy. With over 100 cities housing more than 1 million residents, China has experienced diverse paths of urbanization and a boom in tall building construction. As the government incorporates vertical development into new master plans to concentrate population density, it is crucial to quantify the relationship between structural growth and economic changes to provide strategic guidance. To investigate these dynamics, this research analyzes data at the prefecture level from 2003 to 2018 using differences-in-differences techniques.

2. Background

The construction of skyscrapers in China has experienced rapid growth in the past decade due to factors such as commercial demand, technological progress, and city image construction. This trend has expanded from first- and second-tier cities to third- and fourth-tier cities. Skyscrapers with landmark significance have been established in many places, improving the town's image and popularity. China has become a global center for skyscraper construction, with 753 out of the world's 1,613 skyscrapers over 200 meters located in China. Among the top 10 tallest

buildings in the world, China has six. Skyscrapers have been built in 63 cities across the country, including Hong Kong, Macao, and Taiwan.

Before 2013, the number of new skyscrapers remained relatively stable. However, after 2013, there was a significant acceleration in growth, showing an explosive trend. The number of skyscrapers above certain heights remained stable initially but increased considerably after 2013. By 2019, China had 16 skyscrapers over 400 meters.

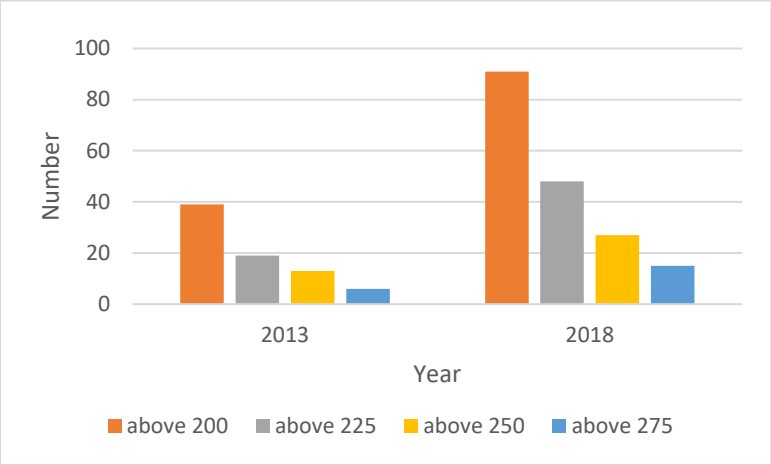

Figure 1: Number of Skyscrapers in China 2013 vs 2018

Shenzhen has the highest number of skyscrapers above 200 meters, accounting for 12.6% of the country's total, followed by Hong Kong, Shanghai, Chongqing, Guangzhou, and Wuhan. Overall, China's construction level for skyscrapers is among the highest in the world.

In terms of construction use, more than half of the buildings are for office spaces, while 12% are for residential use, 4% for hotels, and 30% for mixed-use purposes. Skyscrapers above 400 meters are mainly used for hotels and offices, with most being mixed-use buildings. Only 25% are solely dedicated to office spaces. The number of skyscrapers being constructed in most cities is balanced and aligned with economic and social development. (statista,2023)

However, there are concerns about the risks associated with tall buildings, such as blind excessive construction driven by political achievements. Scholars have differing opinions on the functions and meanings of skyscrapers. In some cases, urban governments prioritize constructing the "newest" and "highest" buildings in pursuit of GDP rankings, without considering the natural ecology, culture, and history of the city. This study aims to provide insight to address this issue.

3. Theoretical Perspectives and Hypothesis

The development of skyscrapers is believed to have a profound impact on cities and urban economies. Here are a few key aspects:

1. The traditional microeconomic model suggests that economically stronger cities tend to have taller buildings. Theory believes that in urban spatial economic models of cities, firms impose transportation cost into their production cost to determine location. The transportation cost is in a functional form of the distance to a pre-determined central business district (Garza & Lizieri, 2016). Residual will be transferred into rents which determine the corresponding optimal height for the building as firm in the city centre. (Anas, Arnot, & Small, 1998; Kraus, 2007)
2. Skyscrapers contribute to urban economic and trade activities. They promote the growth of building materials industries and stimulate economic development. Skyscrapers serve as important economic centers for businesses, research, innovation, and tourism. They generate benefits through property management and advertising. This spatial centralization facilitates industry collaboration networks and boosts urban economic growth. (Fang et al., 2018)
3. Skyscrapers enhance the city's image. As landmark buildings, modern skyscrapers represent the city's cultural identity and elevate its image. Unique architectural styles and iconic structures attract high-end talent, capital, and technology. These buildings also serve as tourist attractions, stimulating urban tourism and generating income. (Ahlfeldt and Barr, 2022; Bertaud and Bruckner, 2005)
4. Skyscrapers foster the agglomeration of high-value-added industries. They become hubs for high-end industries, such as financial services, design consulting, and technical research and development. This concentration of industries promotes the development of high-value-added sectors and improves urban competitiveness. (Henderson et al., 2012)
5. Skyscrapers facilitate talent concentration and drive innovation. By bringing together scientific and technical personnel in R&D and offices, skyscrapers foster collaboration and knowledge exchange. This leads to the creation of new ideas and promotes technological fusion, ultimately driving economic structure upgrading and knowledge creation. (Chau et al., 2007)
6. Skyscrapers optimize urban space and land use. With rising land prices, skyscrapers alleviate space constraints and maximize resource utilization. Their architectural design plays a crucial role in energy efficiency, lifestyle, branding, and infrastructure systems. (Kohlhase and Ju, 2007; Li and Wang, 2020).

In summary, the construction of skyscrapers follows its own rules and mechanisms, and it actively promotes urban development. Through empirical studies, we can examine the impact of skyscrapers on the urban economy.

Skyscraper construction concentrates commerce, tourism, and finance in specific urban areas, resulting in labor, capital, technology, and resource concentration. This reduces transaction costs, facilitates enterprise cooperation, and enables the development of new business forms and economic models. It deepens the division of labor, expands industry connections, and improves productivity, leading to high-quality urban economic development. Based on these observations, we propose the following hypotheses:

Skyscraper construction has a significant economic effect and promotes urban economic development

Hypothesis 1

4. Methodology

4.1. Empirical Model

The dataset is a panel dataset which includes the time series data of the attributes of different cities across time. We consider cities which have skyscrapers as treatment group and determine its effect with a quasi-natural experiment. Theoretically, the difference in differences (DID) is more scientific than other general evaluation methods with a more accurate estimation (Zhao et al. 2022), therefore, we adopt the double difference method to construct this study on skyscraper construction's impact on economic development. Here, we adopt the model suggested in "Skyscraper height and urban development in developing countries: economy and trade" as follows:

$$rgdp_{it} = \beta_0 + \beta_1 \mathrm{sky}_{it} + \beta_2 X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

Model Variable Description:

Where i represents the city and t represents the year. The dependent variable $rgdp_{it}$ is the economic development level of i city in the year t, expressed by the actual per capita GDP of the city. The policy dummy variable sky_{it}, in the core explanatory variable, which reflects whether skyscrapers are constructed in i city in year t. The value is 1 in the year when a city builds a skyscraper and in the subsequent years; otherwise, the value in 0. Here we denote the building with height higher than 200 meters as a skyscraper and we denote the construction completion time on or before June with one year as the same year, any construction beyond June will be considered as the construction for next year. (i.e. If there is repeated construction of skyscrapers in the city, the first construction of skyscrapers shall prevail)

X_{it}, is the other control variable, μ_i represents urban fixed effect, including all city- specific factors that do not change over time, such as geographical location, that affect GDP. ν_t is the year-fixed effect, including the factors that have nothing to do with the specific elements of the city, such as the economic cycle, which only changes over time and affects GDP is the random error.

Table 1: Model Variable Definitions

Variable	Definition
$rgdp_{it}$	Actual per capita GDP of i city at time t
sky_{it}	Dummy (=1) for a skyscraper is constructed in i city at time t
X_{it}	Other control varible
μ_i	Urban fixed effect
ν_t	Year-fixed effect

The estimation coefficient β_1 of the independent variable sky_{it} is the focus of this paper. If β_1 is significantly positive, it means that the construction of skyscrapers positively impacts urban economic development. If β_1 is significally negative, it means that the structure of skyscrapers inhibits the city's economic growth. If β_1 is not significant, there is no direct relationship between skyscrapers and economic development. According to the theoretical perspectives and hypothesis, we would deduct that $\beta_1$should be significantly positive, which means construction of skyscrapers will promote urban economic development.

4.2. Data Source and Description

The data on the construction time and height of skyscrapers used for core explanatory variables in this paper are from Councilon Tall Buildings and Urban Habitat (CTBUH). Individual cities' attribute are the Statistical Yearbook of China's Cities and we subset the statistical data of 290 prefecture-level cities from 2003 to 2018 for the core regression analysis and data from 2019 to 2022 to further project the result for examining the time lagging effect. The CPI data for determining the economic growth comes from the National Bureau of Statistics.

Descriptive statistics are provided in Table 2. As seen from the number of observations for each variable, we use unbalanced panel data. Among them, the dependent variable rgdp is the measurement index of the level of urban economic development. The skyscraper in the main experiment is defined as a tall building with a height of 200 meters or above.

Table 2: Variable Description

Variable	Definition
rgdp	Actual per capita GDP of i city at time t
Sky	Dummy (=1) for a skyscraper is constructed in i city at time t
Fisc	Government fiscal scale, fiscal ratio revenue to budgetary expenditure
Ifru	Social security, number of health workers per 10000 people in city
Fix	Investment in fixed asset (in millions, yuen)
Edu	Level of education, number of primary school per 100 sq. km in city
Cul	Literacy level, logarithm of number of books per capita in city

Table 3: Summary Statistics

Category	Variable	N	Mean	S.D.	Min	Max
Dependent variable	rgdp	4605	1.436	1.638	0.07	19.13
Core explanatory variable	Sky	4625	0.108	0.311	0	1
Control variables	Fisc	4609	0.479	0.228	0.026	1.541
	Ifru	4607	19.794	11.12	0	200
	Fix	4014	0.82	0.774	0.03	7.339
	Edu	4607	7.512	6.288	0.034	66.423
	Cul	4587	-1.111	0.885	-4.857	3.767

5. Regression Results and Analysis

The benchmark regression and time dynamics test are included in this chapter. We first examine the impact of the skyscraper construction on economic development using double differencing method and then test the time effect of skyscraper construction on boosting the urban economic development.

5.1 Benchmark Regression

We used the OLS method to estimate Model (1) and verify the core theoretical hypothesis. We employed the double-fixed effect method of city and year to control for differences and time trends. The results are presented in Table 4.

The results show that the construction of skyscrapers significantly promotes urban economic development. In the first column of Table 4, without adding control variables, the coefficient estimate for the core variable is 0.7443, significant at the 1% level. This confirms that skyscrapers contribute to the economic development of cities, thus validating our hypothesis. However, the R^2 is low, considering it is less than 0.3, thus long model with more explanatory power is required to verify the hypothesis.

To account for the influence of factors like capital, labor, and education on the urban economy, we added these control variables in model 2. The estimated coefficient for the core explanatory variable is 0.3870, also significant at the 1% level. At the same time, the model R^2 is over 0.7, meaning the model is fitting the data well and the independent variable have explanatory power with high statistical evidence. This indicates that the construction of skyscrapers continues to have a substantial impact on economic development. Moreover, adding more variable can also argue that skyscrapers enhance urban awareness, diversify, and specialize industrial agglomeration, and promote urban modernization. Other explanatory variables showed high significance level while the key variable coefficient affected substantially, indicating that the additional variable is playing a critical role in the data regression analysis. From the coefficient, it is showed that skyscrapers optimize industrial structure, strengthen agglomeration quality factors, guide urban spatial development, and drive urbanization, all contributing to economic development. Therefore, hypothesis 1 is verified in Table 4.

The estimated results for other control variables align with expectations. The level of urban economic development is closely related to local governments' preferential policies and autonomy. Thus, the positive effect of government scale, measured by finance, on urban economic development is significant. A more comprehensive urban social security system is favorable for economic development. Higher fixed asset investments are associated with better urban economic development. The presence of well-developed educational infrastructure and higher education levels also correlate with higher levels of economic development.

5.2 Time Dynamics

However, the economic benefits may be a long-term process, and the impact on economic development may change over time, possibly showing a lagging effect. To investigate the time trend effect of skyscrapers, we estimated the effect of building skyscrapers within 1-5 years. The

core explanatory variables were lagged by 1, 2, 3, 4, and 5 years, respectively, and Model (1) was estimated. The results are presented in columns 3 to 7 of Table 2.

Table 4: Regression Result

	Dependent variable: rgdp						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sky	0.8159***	0.3867***	0.4305***	0.4671***	0.5603***	0.5870***	0.5938**
	(0.1587)	(0.1278)	(0.1404)	(0.1609)	(0.1953)	(0.2244)	(0.2377)
Fisc		0.6110***	0.5982***	0.5910***	0.6008***	0.5910***	0.5772***
		(0.1358)	(0.1349)	(0.1347)	(0.1367)	0.1358	(0.1346)
ifru		0.0191**	0.0190**	0.0192**	0.0192**	0.0193**	0.0195**
		(0.0079)	(0.0078)	(0.0078)	(0.0078)	0.0078	(0.0079)
fix		0.7757***	0.7759***	0.7789***	0.7789***	0.7827***	0.7855***
		(0.0782)	(0.0779)	(0.0769)	(0.0769)	(0.0767)	(0.0764)
edu		0.0222***	0.0223***	0.0223***	0.0223***	0.0221***	0.0222***
		(0.0062)	(0.0062)	(0.0062)	(0.0062)	(0.0062)	(0.0062)
cul		0.1274***	0.1258***	0.1234***	0.1225***	0.1187***	0.1202***
		(0.0416)	(0.0414)	(0.0411)	(0.0407)	(0.0402)	(0.0404)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,605	3,993	3,993	3,993	3,993	3,993	3,993
R^2	0.2441	0.7267	0.7129	0.7130	0.7080	0.7042	0.7024

Note: Models 1 and 2 are short and long model respectively, models 3-7 are long model projecting to 5 years later. Standard errors are in parentheses. Significance levels are indicated by * for 5%, ** for 1%, *** for 0.1%.

Statistically, all the estimated coefficients for the core explanatory variables are positive. In the first four years, they pass the significance level of 1%, and in the fifth year, they hold significance at the 5% level. The significance tends to weaken over time. Considering the size of the estimated coefficients, the promoting effect of skyscraper construction on urban economic development increases year by year. Based on statistical characteristics, the economic impact of skyscrapers is most substantial in the fourth year after completion. Therefore, we conclude that the fourth year is the economic bloom of the skyscraper's construction project since kick-off.

Apart from replicating the original result of the replicating report, we seek extension of the original study by extending the time dynamics study to 3 more years to verify the optimal year for economic development and uncover the trend of the data. In table 5, we spotted similar trend as stated above, which state that economic benefit from key variables is diminishing across time, is verified.

Table 5: Extended Regression Result

	Dependent variable: rgdp		
	(8)	(9)	(10)
Sky	0.5957**	0.5989**	0.6012**
	(0.2470)	(0.2514)	(0.2555)
Fisc	0.5688***	0.5630***	0.5612***
	(0.1363)	(0.1345)	(0.1355)
ifru	0.0199**	0.0194**	0.0201**
	(0.0079)	(0.0078)	(0.0080)
fix	0.7887***	0.7867***	0.7734***
	(0.0766)	(0.0753)	(0.0771)
edu	0.0222***	0.0223***	0.0221***
	(0.0062)	(0.0063)	(0.0060)
cul	0.1200***	0.1188***	0.1201***
	(0.0400)	(0.0397)	(0.0412)
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
Observations	3,993	3,993	3,993
R^2	0.7024	0.7010	0.6988

Note: Model 8-10 are long models projecting to 10 years later. Standard errors are in parentheses. Significance levels are indicated by * for 5%, ** for 1%, *** for 0.1%.

6. Conclusion

To conclude, there are statistical evidence on the economic hypothesis that skyscraper construction can will have positive impact on the economic growth. Using data from 290 prefecture-level cities in China from 2003 to 2018, this study employs the DID method to examine the impact of skyscrapers on urban economic development, considering time dynamics. The results demonstrate that skyscraper construction significantly enhances the level of urban economic development, with its positive effect accelerating over time. Apart from the economic growth, the construction of skyscrapers also indicated that it enhances urban awareness, diversify and specialize industrial agglomeration, and promotes urban modernization. However, study showed that the positive effect demonstrated diminishing characteristic. In the time-lagging test, the maximum economic bloom is at the fourth year since the construction project kick-off, since then, the significance level of the key variable demonstrated a weaking trend.

The result is intuitive since the construction project on skyscraper are often positively corelated to the expectation on the cities' economy. Cities with healthy economies will attract investors to invest and hence construction projects are required to aid the upcoming development resource demand. One may say that the relationship between skyscraper and economic development are not causal driven by skyscraper construction as cities with strong economy require more

skyscraper, not the other way around. However, this cannot be further away from the truth. Building skyscrapers promotes an image of a highly developed city, it also improves the utilization efficiency of social resources. All in all, by theoretical approach and empirical analysis, we have shown that the skyscraper is one of the driving factors for economic development.

7. Reference

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