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Analysis of the Factors Influencing the Skyscraper Development Boom - An Empirical Analysis Based on 20 Cities

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Abstract: In order to strengthen urban and architectural landscape management, the government strictly restricts the blind planning and construction of super high-rise skyscrapers everywhere. There have been theoretical studies on the influence factors of skyscrapers. However, no definitive conclusion has been reached on the elements that are fueling China's skyscraper development boom. Through literature combing, nine impact factors were selected to conduct an empirical study of skyscraper impact factors on data from the top 20 cities with skyscrapers in Chinese mainland between 2001 and 2018, including number of skyscrapers per city, nominal GDP by city, area of built-up area by city, urban population density, height restriction policies in cities, duration of the city's tallest skyscraper, business cycle, global city index, tertiary industry share, commercial land value, land sale revenue, average age of mayors and city secretaries in each city. According to the complete FGLS regression, the number of skyscrapers is influenced by GDP of the city, built-up area, policy, the global city index, and the age of municipal leaders. GDP, global city index and the number of skyscrapers owned by cities have a significant positive correlation while built-up area, age of officials and the number of skyscrapers owned by cities have a negative correlation. Based on this, the government should consider the economic strength of cities, match the city positioning and urban functions and consider the stability of governance when building skyscrapers.

Keywords: Skyscrapers, Impact Factors, Urban Economy

1. Introduction

China has continued to extend its autonomy and openness since joining the WTO in 2001. The number of skyscrapers has been increasing in tandem with economic growth, as has the height. At present, China's height restriction policy and most statistics take 150m as the boundary, so this paper defines skyscrapers as buildings of 150m and above. As of December 2021, China has built 2662 skyscrapers of 150m and above, ranking first in the world.

The skyscraper construction boom has attracted more capital to cities on the one hand, and negatively impacted urban landscape on the other. In 2020, the Ministry of Housing and Construction and the National Development and Reform Commission of China had introduced policies to restrict the blind construction of skyscrapers, but there is no definite conclusion as to what factors have led to the "proliferation" of skyscrapers. At present, there are relevant theories to sort out [1]. However, the influence of skyscrapers should be discussed in the context of the actual situation in China. In this paper, Traditional economic theories, game theory, business cycle theory, global city theory, spatial economics theory, political economy theory, and literature review are used to choose the influencing elements of 20 Chinese cities[1].

2. History and Debate

According to classical economic theory, skyscraper construction is linked to GDP and urban area. In terms of GDP, when regional GDP rises, more capital can be spent in

[1] The 20 cities include: Beijing, Tianjin, Shenyang, Shanghai, Nanjing, Hangzhou, Ningbo, Xiamen, Qingdao, Zhengzhou, Wuhan, Changsha, Guangzhou, Shenzhen, Chongqing, Chengdu, Kunming, Xi'an, Suzhou, Dongguan.

skyscraper development, and skyscraper construction can attract additional investment, resulting in an increase in regional GDP [2]. On the other hand, in terms of urban area, the closer to the city center, the higher the land rent. Skyscrapers are mostly located in CBDs, where developers facing high ground rents need to increase the height of their buildings to ensure a return on investment. Geographically contracting cities (or cities with high density) should have higher building heights and more skyscrapers than those cities where expansion is limited by geography or regulation.

Game theory explains the skyscraper race phenomenon in terms of developer competition versus urban competition. Economists and architects Clark and Kingston [3] determined the economic height of a skyscraper using the relative indicator measure of yield. The H-S game model proposed by Helsley and the C-S model proposed by Barr provide a reasonable explanation for this phenomenon. Helsley [4] argues that even when rental yields are chronically low, building skyscrapers can improve personal reputation. This effect can partially offset the lost costs, and the optimal height occurs when personal reputation exactly offsets the lost costs. However, Barr [5] believes that the H-S game model overemphasizes the importance that real estate openers place on personal reputation. Additional than developer psychology, he believes there are many other impacts. He defines the C-S model as a division of the need for height into two sources: economic and reputation. An empirical analysis was conducted with two cities, New York and Chicago, and a two-city game relationship was found. However, by analyzing the actual situation in China [6], it is found that domestic cities are not simply in a twocity competition relationship, and the construction of skyscrapers in China is also related to many other factors.

The business cycle explains the construction of skyscrapers in terms of capital misallocation. Scholars, represented by economist Lawrence, have found that the tallest buildings in the world are built almost exclusively during recessions, a phenomenon known as the "Lawrence Curse" [7]. This phenomenon is known as the "Lawrence Curse". According to Thornton and others, the construction of skyscrapers is a sign of economic crisis. Although the trend of skyscraper construction and GDP are similar, skyscrapers are usually built later than GDP [8]. This is due to the fact that skyscrapers are mostly built when interest rates are low, i.e., when the economy is booming, in order to reduce costs, the construction of skyscrapers begins. Because of the construction cycle, the economy is already in recession when skyscrapers are built, so skyscraper construction can effectively predict the business cycle [9]. In addition to the capital mismatch explanation, there are also researchers who hold another view. Barr believes that the actual number of skyscrapers is highly positively correlated with the level of economic and social development. By conducting Granger causality tests on the relationship between skyscraper heights and business cycles, they argue that the announcement and completion dates of skyscrapers have little correlation with the peaks or troughs of the economic cycle [10]. The height of skyscrapers and the output are cointegrated, and that height does not determine output, while GDP is what determines height.

Global city theory suggests that in developing countries, even cities with strict height control will "break the rules" by increasing the height of skyscrapers in order to compete for more mobile capital and to build the image of the city. Skyscrapers, as iconic buildings, can shape and promote the image of a city. In the process of global urban competition, capital flows around the world, and skyscraper construction can compete for this capital, such as the concentration of advanced productive services to attract highly qualified labor. Skyscrapers tend to concentrate high-end services and commercial and other attributes, which can drive the increase in demand for related commercial retail, hotels, offices, etc., making more senior employment gather. The development of skyscraper has been completed in developed-country cities as part of the global capital agglomeration process. Skyscrapers, on the other hand, are the architectural backdrop of "global" cities in emerging countries [11], and the goal is to bring more capital into the city to help it grow rapidly.

According to the general equilibrium theory of land in the theory of spatial economics, the closer to the urban center, the higher the land rent. Classical spatial economics suggests that there is a complementary relationship between business transportation costs and land rents, and that these transportation costs are a function of the distance to the intended CBD. The closer the CBD, the lower the transportation costs which means the higher the land rents. Skyscrapers are usually located in urban centers, and in order to ensure the return on investment, they can only be achieved by increasing the building height to improve space utilization, so the closer the CBD area is, the more skyscrapers there are. In addition, the agglomeration effect and location stickiness also explain the location of skyscrapers, and the agglomeration of tertiary industries leads to the construction of a large number of skyscrapers [1]. The concentration of tertiary industries leads to the construction of a large number of skyscrapers. Skyscraper tenants are usually in the tertiary sector, such as finance. The economic activities and effects generated by the tertiary sector have a centripetal force to gather in the city center [12]. This agglomeration effect brings good development opportunities for enterprises. In addition, due to the existence of location stickiness, the tertiary industry tends to locate in urban centers in the development process because they are path-dependent on the strategic resources of the area, and the mature business resource conditions in urban CBD also bring various social resources for enterprises to enhance their competitiveness. Therefore, the location of skyscrapers is often closely related to industry and land prices, and changes in the tertiary industry and land prices will have an impact on skyscrapers.

Political economy theory suggests that the construction of skyscrapers may be relevant to local governments. In China, land concessions are an important part of local government revenue and also an important source of income for local governments. Local governments may have a tendency to build too many skyscrapers in order to raise local government revenue. According to People's Daily, the blind climbing of skyscrapers is the result of face-saving projects. Officials are more inclined to build skyscrapers, especially young government officials, in order to utilize them as their political achievements. So the younger the officials are, the more inclined they are to build skyscrapers.

3. Baseline and Test Models

We integrate the current scenario in China with the screening of skyscraper effect elements. In this research, we use the frequency statistics method to create an effect factor system based on this existing theory and the circumstances of our country. We offer six theoretical models, including the benchmark model, using the theoretical analysis approach of classification.

3.1. Establishment of the System of Impact Factors

Establishing the system of influence factors of skyscrapers by theoretical analysis method and frequency statistics method. Firstly, the existing skyscraper-related literature was sorted out by theoretical analysis method and categorized. Secondly, the frequency statistics were used to identify the influencing factors mentioned in the literature and identify the influencing factors with higher frequency. Finally, the impact factor system was established by screening the impact factors with the Chinese reality.

By reading a large amount of literature, the following literature was selected as a generalized sample for the summary. The results of frequency statistics are shown in Table 1.

The statistical results show that there are relatively more research results mentioned for the aforementioned theories. According to the frequency statistics in Table 1, 77.78% of the studies in the literature focus on ground rent, game, global city, population, policy, GDP, use, construction cost, economy, area, industry. Among them, GDP, area and economic factors correspond to traditional economic theories. Considering that the research indexes of literature related to economic factors are vague and indeterminable, GDP and area are used to represent traditional economic theories. Game theory uses the number of years that the tallest building in the city occupies the top of the skyscraper height in the city as the indicator. The global city theory uses the global city index as an indicator. Use and industry correspond to the spatial economics theory, where use is taken into consideration when selecting the number of skyscrapers, Industry is integrated with the aforementioned spatial economics theory, and the proportion of tertiary industry in GDP is chosen as the influence factor. The essence of land price is the capitalization of future land rent, so this paper takes commercial land price as the influence factor of land rent to measure its influence on the number of skyscrapers. In addition, due to the macro level of the study and the low feasibility of data collection, construction costs are not taken into consideration in this paper. Finally, population, policy laws and regulations are used as control variables in the model in the subsequent study, where population is reflected by the population density indicator.

In addition to the influencing factors above, political performance is included in the model even though the frequency is low due to the specificity of the Chinese market. Within the term of office, the official is more likely to be promoted if the official creates significant economic benefits for the local area or builds a large project. So there is a correlation between skyscraper construction and officials' performance. Fiscal expenditure of local government and the average age of local officials are included in Table 1 as factors related to officials' performance.

In summary, GDP, area, population density, policy, years of occupying the top of the list, global city index, the proportion of the tertiary industry, land price, fiscal expenditure of local government, and average age of local officials are selected as influencing factors, and population density and policy laws and regulations are included in the model as control variables. Specific information such as the explanation and source of each influence factor is shown in Section 3.3.

Table 1. *Frequency statistics of impact factors.*

Impact Factor	Frequency	Scholars	Impact Factor	Frequency	Scholars
Ground rent	13	Barr [13], Garza [14], Sullivan [15], Ahlfeldt [16], Zeng [1] Auerbach [17], Koster [17], Ahlfeldt [18], Klaber [19], Koster [20], Koster [17], Al-Kodmany [21], Han [22]	Number of office staff	1	Barr [13]
Business cycle	12	Garza [14], Boyle [23], Jadevicius [24], Barr [10], Engelhardt [9], Rovelli [25], Thornton [26], Barr [27], Löffler [28], Zeng [1], Watts [2], Skelton [29]	Effective interest rate of commercial paper	1	Barr [13]
Gaming	11	Garza [14], Barr [6], Barr [30], Barr [5], Barr [31], Helsley [4], Nase [32], Zeng [1], Koster [20], Al-Kodmany [21], Westerhuis [33],	Sunk costs	1	Watts [2]
Global cities (index)	11	Garza [14], Acuto [34], Graham [35], Zeng [1], Watts [2], Al-Kodmany [21], Al-Kodmany [36], Barkham [37], Chen [38]	Underground depth	1	Barr [13]
Population	10	Barr [13], Barr [6], Wang [39], Li [40], Auerbach [41], Barr [42], Watts [2], Al-Kodmany [21], Chen [38], Liang [43]	Building type	1	Barr [13]
Policy	9	Barr [13], Garza [14], Appert [44], Titman [45], Ponzini [46], Zeng [1], Sun [47], Watts [2], Al-Kodmany [21],	Plot size	1	Barr [13]
GDP	8	Garza [14], Barr [6], Barr [10], Wang [39], Li [40], Barr [42], Barkham [37], Liang [43]	Plot shape	1	Barr [13]
Use	6	Barr [13], Garza [14], Sullivan [15], Watts [2], Ahlfeldt [18], Skelton [29]	Surrounding building height	1	Barr [13]

Impact Factor	Frequency	Scholars	Impact Factor	Frequency	Scholars
Construction costs	5	Barr [13], Barr [48], Barr [31], Tan [49], Ahlfeldt [18]	Office rent	1	Barr [31]
Economy	4	Parker [50], Formaneck [51], Watts [2], Chen [38]	Apartment prices	1	Barr [31]
Area	4	Garza [14], Wang [39], Barkham [37], Liang [43]	Total retail sales of social consumer goods	1	Wang [39]
Industry	4	Barr [6], Nase [32], Wang [39], Liang [43]	Total retail sales of social consumer goods	1	Wang [39]
Technological advances	3	Garza [14], Al-Kodmany [21], Chen [38]	Urban road area	1	Li [40]
Population density	2	Garza [14], Li [40]	Drainage pipe length	1	Li [40]
Foreign direct investment	2	Li [40], Liang [43]	Number of buses	1	Li [40]
Local government financial expenditures	2	Barr [6], Barr [42]	Number of cabs	1	Li [40]
Average age of local officials	2	Barr [6], Barr [42]	Residents' happiness index	1	Barr [52]
political climbing	2	Zeng [1], Chen [38]	Black leverage effect	1	Watts [2]
Profits	2	Żelazowski [53], Westerhuis [33],	Tourism	1	Leiper [54]
return on investment (ROI)	2	Barr [48], Clark [3],	Land parcel size	1	Barr [55]
Distance to commercial center	2	Barr [13], Barr [55],	Bedrock depth	1	Barr [55]
Employment rate	2	Barr [13], Han [22]	Infrastructure	1	Al-Kodmany [21]
Perspectives	2	Nase [32], Westerhuis [33]	International finance	1	Al-Kodmany [21]
Demographics	1	Al-Kodmany [21]	Is it a European city	1	Barkham [37]
Culture	1	Parker [50]	Whether mountainous areas	1	Liang [43]
Service industry share	1	Li [40]	Is the municipality directly under the central government	1	Liang [43]
Fiscal deficit	1	Barr [6]			

3.2. Model Construction

This paper first establishes the baseline mapping model, which uses two variables extracted from the traditional microeconomic theory, GDP, and area. This baseline model includes panel (it), cross-sectional (i) and time series (t) variables. A single variable is added to the baseline model each time, and finally all variables are put into the model. In the model, all variables except dummy variables, periodic terms and variables in percentages take logarithmic form for better statistical inference.

3.2.1. Benchmark Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\ \text{Population Density}_{it};\text{Policy}_{i}) \quad (1)$$

In this section, a benchmark model is developed in order to test the selected impact factors individually or in combination. The baseline model includes GDP and Area from traditional microeconomics. The control variables population density and policy are uniformly included.

The dependent variable represents the number of skyscrapers. In this paper, the number of skyscrapers rather than their height is chosen as the dependent variable. Because skyscraper height is susceptible to a variety of subjective factors such as route limits, the number of skyscrapers is less influenced than their height.

The independent variable is the nominal GDP of the city in that year and Area represents the built-up area of each city. The control variables contain the city's population density and height restriction policy.

Considering that the skyscrapers higher than 150m may not exist in the selected cities, the form of $\ln(\text{Numbers}_{it}+1)$ was used in building the model. The data on the number of skyscrapers were extracted from the skyscrapercenter website, and the data on completed skyscrapers in the 20 cities on the list in mainland China between 2001 and 2018 were selected for this paper.

3.2.2. Game Theory Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\ \text{Population Density}_{it};\text{Policy}_{i};\text{Period}_{it}) \quad (2)$$

Game theory uses the number of years that the tallest building in the city occupies the top spot in the height of the city's skyscrapers (Period_{it}) as a measure. This variable varies from a range of 0 to 19 years. This number may be larger than the entire period in the database (18 years) because some cities did not have record-breaking skyscrapers in the period 2001-2018. This is a panel variable because when a skyscraper is at the top of its city's building height list for a long time, it has a significant preemptive effect on the presence of competitors, and also suggests that there may be overbuilding of skyscrapers. In addition, since some cities do not have skyscrapers at the beginning of the statistical year, this indicator is assigned a value of 0 in the corresponding year for these cities. this paper assumes a positive correlation between this variable and the number.

3.2.3. Business Cycle Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Cycle}_{it}) \quad (3)$$

In this paper, the results of HP filtering of GDP per capita for each city in stata are used to represent the business cycle Cycle_{it}. To avoid multicollinearity with the nominal GDP of each city in the benchmark model, the data of GDP per capita of each city in the statistical yearbook are used in this paper. Since the macroeconomy does not have a definite time trend, a hodrick-prescott filter is applied to it using stata to decompose GDP per capita into trend and cyclical components, and the cyclical term is extracted as the business cycle data. Since skyscrapers start to be built when the economy is booming, and over time the economy is mostly in a period of decline or even underestimation when the skyscrapers are completed, it is assumed that there may be a negative correlation between the number of skyscrapers and the business cycle.

3.2.4. Global City Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{GAWC}_{it}) \quad (4)$$

The higher the ranking on GaWC, the greater the degree to which a city attracts brand-name companies to its city to enhance its competitiveness. The GaWC ranking is based on internationalization and participation in international affairs and influence, representing a city's position and integration in the global economy.

Table 2. *Global City Index Assignment.*

City Rating	Assignment
Alpha++ (Premium City)	-
Alpha+ (strong first line)	1.0
Alpha (S1)	0.9
Alpha- (weak first line)	0.8
Beta+ (strong second tier)	0.7
Beta (middle two lines)	0.6
Beta- (weak second line)	0.5
Gamma+ (strong trine)	0.4
Gamma (Middle Trine)	0.3
Gamma- (weak trine)	0.2
HighSufficiency (Highly Self-Contained Cities)	0.1
Sufficiency (self-contained cities)	0.1
Not on the list	0.0

Each city is assigned a value according to its city rank in the GAWC website. Since there is no Alpha++ (Premium City) in China, the remaining 12 ranks are assigned a value according to their city index rank as Table 2. We assumes that the higher the global city index rank, the more skyscrapers there are.

3.2.5. Spatial Economics Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Price}_{it}) \quad (5)$$

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Industry}_{it}) \quad (6)$$

Industry denotes the share of tertiary industry and Price denotes the land price of commercial land. Based on the agglomeration effect and locational stickiness, two influencing factors, tertiary industry share of GDP and commercial land price, are selected as independent variables included in the model. Since the data of tertiary industry share of each city in 2003 are missing in the yearbook, this paper takes the average of 2002 and 2004 data as the data of 2003 in data processing. In addition, the data of city-wide tertiary industry share of each city does not exist in 2003 and 2017, and the data of municipal districts are used instead. In this paper, we assume a positive correlation between the share of tertiary sector and the number of skyscrapers, and the same for land prices.

3.2.6. Political Economy Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Isr}_{it}) \quad (7)$$

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Age}_{it}) \quad (8)$$

Isr stands for state-owned land use rights, and Age represents the average age of mayors and municipal party secretaries in each city. According to the theory of political economy, the amount of state-owned land use right concessions and the average age of mayors and municipal party secretaries of each city are selected as independent variables to be included in the model. The mayors and municipal party secretaries of each city who have been in office for less than half a year are counted as half a year, and those who have been in office for less than a year but more than half a year are counted as one year. In this paper, it is assumed that the average age of city mayors and city secretaries is positively correlated with the number of skyscrapers built in order to improve the political performance of local officials.

3.2.7. Integrated Model

$$\ln(\text{Numbers}_{it}+1) = f(\text{GDP}_{it};\text{Area}_{it};\text{Population Density}_{it};\text{Policy}_{i};\text{Period}_{it};\text{GAWC}_{it};\text{Cycle}_{it};\text{Industry}_{it};\text{Price}_{it};\text{Isr}_{it};\text{Age}_{it}) \quad (9)$$

Finally, all the influencing factors mentioned above were included in the comprehensive model to verify whether the relationship between the influencing factors and the number of skyscrapers was consistent with the results of the model mentioned above. If the variables in model (9) have the same results as the corresponding model variables mentioned above, it is proved that the expectation is the same as the hypothesis conclusion.

3.3. Data Sources and Empirical Strategy

Based on the literature analysis and frequency statistics method to construct the skyscraper impact factor system, this part collects data to establish the skyscraper impact factor database. The basic information of each impact factor is shown in Table 3.

Table 3. *Basic information of data.*

Variables	Type	Unit	Source	Remarks
$Numbers_{it}$	Panels	unit	www.skyscrapercenter.com	Number of skyscrapers per city
GDP_{it}	Panels	Billion	data.stats.gov.cn Municipal statistical offices	Nominal GDP by city
$Area_{it}$	Cross-section	Square kilometers	olap.epsnet.com.cn	Area of built-up area by city
Population $Density_{it}$	Panels	People/km2	olap.epsnet.com.cn	Urban population density
$Policy_{i}$	Cross-section	Virtual	Related Policy Documents	Existence of height restriction policies in cities
$Period_{it}$	Panels	Year	www.skyscrapercenter.com Calculation	Duration of the city's tallest skyscraper
$Cycle_{it}$	Panels	-	HP filtering of GDP per capita for each city	Business cycle
$GAWC_{it}$	Panels	Virtual	www.lboro.ac.uk/gawc	Global city index
$Industry_{it}$	Panels	%	China City Statistical Yearbook	Tertiary industry share
$Price_{it}$	Panels	Yuan/sqm	Ministry of Land and Resources of China China Land Value Information Service Platform	Commercial land value
Isr_{it}	Panels	million yuan	olap.epsnet.com.cn	Land sale revenue
Age_{it}	Panels	age	Select City Network statistics and Calculation	Average age of mayors and city secretaries in each city

The data collected contain panel data (Numbers, GDP Populationdensity, Period, GAWC, Price, Industry, lsr, Age), cross-sectional data (Area, Policy), and time series data (Cycle). Descriptive statistics of the variables are presented in Table 4.

Table 4. *Descriptive statistics of variables.*

Variables	Observations	Average value	Standard deviation	Minimum value	Maximum value
Numbers	360	25.86	34.52	0.00	229.00
GDP	360	7143.27	6196.49	558.33	36011.82
Area	360	767.53	338.98	345.49	1445.54
Populationdensity	360	3582.97	2892.94	535.00	15055.00
Policy	360	0.60	0.49	0.00	1.00
Period	360	7.46	4.67	0.00	19.00
Cycle	360	4729.55	2946.82	1053.11	9976.68
GAWC	360	0.21	0.30	0.00	1.00
Industry	360	53.52	8.48	32.35	80.98
Price	360	11159.72	10597.88	1389	57809
lsr	360	1375382.00	2795705.00	113.00	20276041.51
Age	360	54.39	4.29	43.00	67.50

This paper uses Stata to perform regression analysis on the impact factors screened in the previous paper. The Hausman test is first performed and the fixed effects model is chosen. This paper uses 10 models for regression separately.

Model 1 uses traditional economic theory and contains two variables of GDP and area. Model 2 adds two control variables of population density and policy planning to it. Game theory is included in model 3. Model 4 represents the business cycle model, while model 5 represents the global city model. Model 6 and model 7 detect the theory of spatial economics, where model 6 adds land price on the basis of the benchmark model, model 7 adds the share of tertiary industry. The political economy is represented by models 8 and 9. Model 8 incorporates land concessions, whereas Model 9 adds officials' ages. Model 10 includes all influencing factors.

The heteroskedasticity and serial autocorrelation of the model are tested considering the risk of failure of the general Hausman test in the case of heteroskedasticity and serial autocorrelation. For the possible heteroskedasticity problem of the model, a modified Wald test is used to test the between-group heteroskedasticity of the panel data, and the test results show that there is between-group heteroskedasticity in this panel data, and the autocorrelation problem of this panel data according to the Wooldridge test.

In order to solve the heteroskedasticity and serial autocorrelation problems of the model, full FGLS (feasibility generalized least squares) estimation is used for processing in this paper. The failure risk problem is solved after using the full FGLS treatment. The regression results are shown in Table 5.

4. Empirical Results

(1) There is a significant positive correlation between GDP,

the Global Urban Index and the number of skyscrapers in a city.

The GDP correlation coefficient is above 0.5, which supports the existing theoretical literature on GDP as a reasonable predictor and is consistent with the research hypothesis. This is the same result as Barr et al.'s study, indicating that the construction of skyscrapers in China is largely synchronized with economic demand [6], and with the growth of regional GDP, more capital can be invested in the construction of skyscrapers.

The global city index correlation coefficient is above 0.4, which confirms that the city image created by skyscrapers does have a positive effect on the competitiveness of cities [1]. In 2017, the Triangle Tower (180m) received a building permit, the Paris Twin Towers (180m and 122m respectively) officially started construction, and the new site of the Palais de Justice (160m) was completed. Our cities such as Shanghai and Guangzhou are ranked among the first-tier cities in the 2018 GAWC classification, and they create their own city brands with their towering skylines, driving the development of urban services and injecting vitality into the cities.

(2) The results of built-up area and officer age are significant, but the regression coefficients are contrary to the research hypothesis.

The regression coefficients of built-up area are positive and exceeds 0.4, indicating that the larger the built-up area of a city, the more skyscrapers are built, which is inconsistent with the hypothesis that "the built-up area of a city is negatively correlated with the number of". The reason is that the traditional theory is based on the premise the built-up area remains unchanged for a long time, the boundaries of foreign cities in developed countries have been relatively solidified, and can only develop into the air, such as New York, Chicago, Los Angeles and other cities. On the one hand, because their own municipal areas are usually much smaller than China, on the other hand, their urbanization process has basically ended, resulting in the built-up area limited. The only way to increase the available space is to build skyscrapers. The cities in China are at a different stage of development, the mid-urbanization stage making the large and medium-sized cities in China still at the stage of urban space expansion [56]. This rapid urbanization phenomenon is associated with high economic growth targets [57], and GDP is the most fundamental driver of the rise in built-up area [58]. Accelerated urbanization has led to an influx of more people into these cities, and industrial development due to the economic boom has led to a continuous expansion of city size and a simultaneous increase in the number of skyscrapers.

The regression coefficients of officials' age are positive and greater than 0.2, contrary to the previous hypothesis that "the younger the official, the more inclined he or she is to build skyscrapers". Other areas of literature suggest that there is indeed pressure for promotion targets after a certain age of domestic officials, and the older the official is, the less likely he or she is to receive political promotion [59]. It has been found that, using 54 years of age as the cut-off, the probability of promotion of mayors and municipal party secretaries decrease significantly after exceeding this age, and the possibility of retiring to the second line rises rapidly [60]. Under the pressure of promotion, older officials may have a greater preference for investment to drive economic growth and a stronger incentive to build skyscrapers in order to highlight political achievements.

(3) The correlation between the duration of the city's tallest skyscraper, business cycle, tertiary industry, the price of commercial land and local government land sale revenue and the number of skyscrapers completed is relatively weak.

The business cycle regression coefficients are all less than 0.1. The possible reason of the insignificant results for the business cycle is that the time period included in this paper is short, and neither the business cycle nor the real estate cycle in China has gone through a complete cycle in this time period. It is also possible that the results are not significant because the business cycle itself is more directly linked to the country or region, and it may not be possible to synchronize the business cycle with the city's economic development for individual cities [1].

The price of commercial land is not significant at the 10% level, and the correlation coefficient of land sale revenue is below 0.1, which proves that the price of commercial land and land sale revenue are not reasonable influencing factors for the number of skyscrapers in cities. In order to ensure the smooth completion of skyscrapers, the government mostly gives policy concessions in the development process to ensure the interests of developers. For example, the government gives preferential policies such as land premiums and income tax equivalent subsidies to projects during the construction process. Since the purpose of local government is to import industries and indirectly increase the value of surrounding land, rather than directly earning local revenue through land concessions, the correlation between land price, land sale revenue and the number of skyscrapers is weak.

The correlation coefficient of tertiary industry is 0.1 and below, which proves that tertiary industry is not a reasonable influencing factor for the number of urban skyscrapers. Domestic skyscraper tenants usually have a high proportion of financial and Internet industries, so the financial and Internet industries in the tertiary industry may be a reasonable predictor of skyscrapers. However, the share of finance and Internet in the tertiary industry is not high in some cities in China. For example, the total factor productivity of the financial industry in Beijing is much lower than the national average [61], while foreign trade in Guangzhou occupies an important position in the tertiary industry. In this case, the composition of the tertiary industry in China is not consistent with that of foreign countries, which leads to insignificant tertiary industry results.

The Period variable is not significant at the 10% level, which indicates the correlation between the duration of the city's tallest skyscraper and the number of skyscrapers is extremely weak, and the phenomenon of developer gaming in China is not obvious. In order to prevent skyscrapers from rotting, the government usually designates enterprises with strong development strength to be responsible for the construction of skyscrapers, such as the first skyscraper site in Shenzhen-Shantou Cooperation Zone is constructed by Greenland. Nanchang Ping An Financial Center is developed by Ping An Life Insurance Co. of China. Among the top 20 skyscrapers in China in terms of height, state-owned enterprises invest and develop 65% of them. These phenomena show that the construction of skyscrapers in China is less relevant to the developers' game and more to the local government's decision.

Table 5. *Full FGLS regression results.*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
lnGDP	0.846***	0.842***	0.537***	0.772***	0.863***	0.821***	0.869***	0.841***	0.592***
	(0.030)	(0.030)	(0.045)	(0.027)	(0.029)	(0.027)	(0.027)	(0.027)	(0.039)
lnarea	0.438***	0.432***	0.676***	0.422***	0.443***	0.445***	0.465***	0.476***	0.568***
	(0.114)	(0.117)	(0.096)	(0.074)	(0.086)	(0.096)	(0.100)	(0.098)	(0.057)
lnpopulationdensity	-0.033***	-0.032**	-0.028**	-0.027**	-0.028**	-0.028**	-0.030***	-0.029***	-0.025***
	(0.012)	(0.014)	(0.011)	(0.011)	(0.013)	(0.013)	(0.009)	(0.009)	(0.008)
policy	-0.263***	-0.271***	-0.230***	-0.276***	-0.232***	-0.269**	-0.254***	-0.248***	-0.248***
	(0.087)	(0.093)	(0.079)	(0.071)	(0.069)	(0.106)	(0.078)	(0.078)	(0.045)
lnperiod1		0.014							0.044***
		(0.009)							(0.009)
cycle			0.000***						0.000***
			(0.000)						(0.000)
GAWC				0.472***					0.436***
				(0.046)					(0.043)
lnprice					0.005				0.056***
					(0.013)				(0.016)
industry						0.010***			0.004***
						(0.001)			(0.001)
lnlsr							-0.013***		-0.021***
							(0.004)		(0.004)
lnage								0.251***	0.271***
								(0.056)	(0.062)
_cons	-6.892***	-6.832***	-6.409***	-6.371***	-7.209***	-7.322***	-7.154***	-8.163***	-7.830***
	(0.790)	(0.819)	(0.660)	(0.530)	(0.604)	(0.657)	(0.633)	(0.631)	(0.339)

5. Policy Recommendations

Only when the skyscraper construction matches with the economic strength of the city, the construction of skyscrapers is reasonable. The skyscrapers built in isolation from the economic development of the city will only increase the risk of bubble. It is true that cities in China have the purpose of establishing their city image globally or regionally through the construction of skyscrapers. Therefore, the government should take the economic development level of each city into account when planning, to avoid the phenomenon of blindly climbing high. Different cities should regulate on the basis of sorting out their own economic development needs, and do a good job of monitoring, early warning and prevention and control of the corresponding bubble risk.

Besides, the construction should match the positioning and function of the city. It is widely believed that skyscrapers represent the wealth and mark the global competitiveness of a city. This paper also finds a correlation between skyscrapers and city positioning through empirical analysis. Therefore, the government needs to consider the city's integration into the global economic network in addition to the city's economic strength when building skyscrapers. The more global and regional a city's corporate functions are, the more connected it is to the global economy and the more influence it has on the world. Therefore it is important to match the construction of skyscrapers to the city's positioning and urban functions. Emerging market cities must respond quickly to new economic conditions, such as the influx of overseas companies, in which case restrictions on skyscraper construction can be moderately relaxed. However, not all cities can build skyscrapers in a positive way, it is also necessary to avoid the blind worship of skyscrapers.

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