Title: **Reaching for the Sky: The Determinants of Tall Office Development in Global Gateway Cities**

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There are numerous hypotheses about the social and economic processes that lead to the development of skyscrapers, but empirical evidence is scarce. In this article, the authors take an initial look at the determinants of office skyscraper development in cities across the globe. Ultimately, the aim is to better understand why cities have different amounts of floor space in skyscrapers. Is it only geographic and economic processes at work, or are other regulatory or behavioral factors at play?

Skyscrapers are widely believed to reflect a city's wealth and its global competitiveness. Indeed, certain cities promote the construction of skyscrapers to enhance their "brand." The race for the tallest skyscraper in the twentieth century led to the development of the Empire State Building in New York, and in the twenty-first to the development of the Burj Khalifa in Dubai and Shanghai Tower in Shanghai. From an urban economics perspective, the high price of land at the center is due to scarcity and the premium occupiers pay for access. Skyscrapers reflect the optimal allocation of capital to this very expensive land resource. It is also possible that skyscrapers create productivity gains due to within-building agglomeration economies. Here, density of employment fosters frequent face-to-face contact and knowledge sharing, which in turn leads to product and process innovation. So, there are numerous hypotheses about the social and economic processes that lead to the development of skyscrapers, but empirical evidence is scarce.

In this article, the authors take an initial look at determinants of office skyscraper "development" in cities across the globe. In doing so, the authors depart from the regional or national scope that the few earlier studies on skyscrapers have adopted (Barr et al. 2015; Helsley and Strange 2008) by examining the geographical and economic factors that theory tells us lead to development of skyscrapers in a global context.

The authors' data on skyscrapers is from the CTBUH Skyscraper Center database: specifically, its record of skyscrapers with an office use function. Rather than looking at the total number of skyscrapers, or merely their individual or aggregate height, the authors use the number of floors in the total stock of office skyscrapers in a city as a proxy for the total internal floor space of this type of building. This is the dependent variable.

The sample from CTBUH's database includes 2,358 skyscrapers[1] with an exclusive or mixed office use from 83 countries worldwide. The geographical distribution (see Figure 1) illustrates that the United States and Asia, with cities such as New York, Tokyo, Shanghai, and Hong Kong, have the most skyscrapers, defined, for the purpose of this paper, as office buildings of 100 meters' or greater height. Between 2000 and 2015, skyscraper development has been most concentrated in cities within fast-growing emerging markets such as China (see Figure 2). Nevertheless, in terms of number of floors, New York still tops the list, followed by Tokyo, Hong Kong, Dubai, Chicago, Sydney, and Shanghai.

The hypothesis is that four factors explain the quantum of space within skyscrapers: the Gross Domestic Product (GDP) of the city, the land area of the city, the global connectedness of the city, and the presence of land-use regulations that place restrictions on individual building height for aesthetic or public safety reasons. In the next section each of these is first examined in turn, then in a multivariable framework.

Drivers of Skyscraper Development

While a city's GDP is both cause and consequence of skyscraper development, in

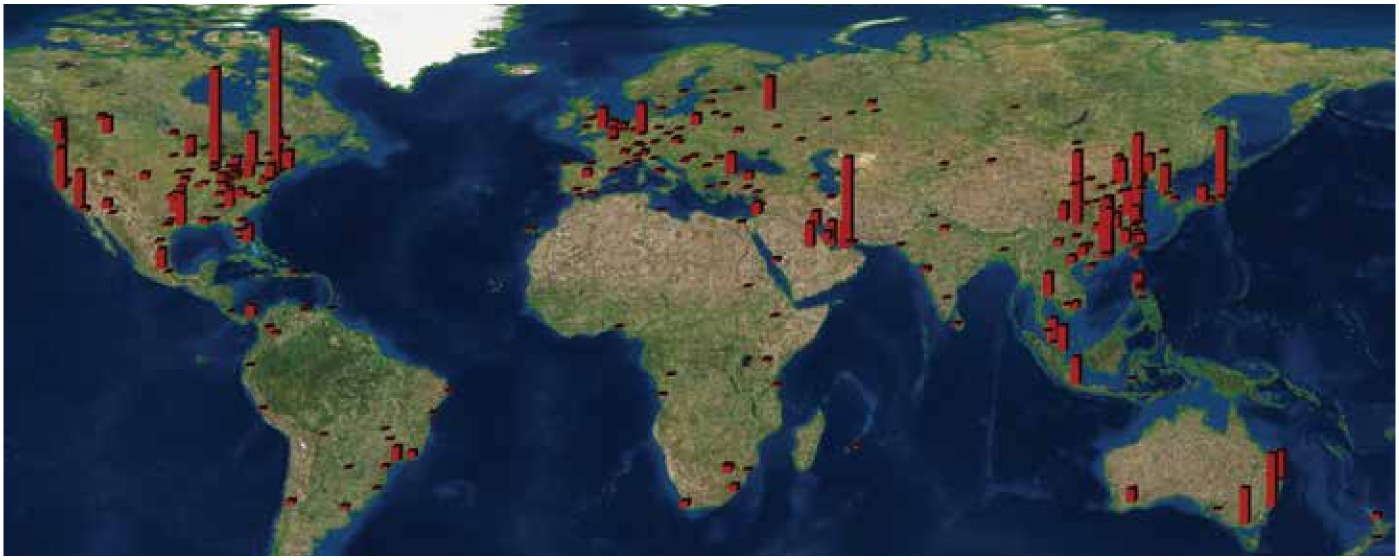

Figure 1. The total number of skyscrapers[1] as of the end of 2015. Source: CTBUH & CBRE Research 2016.

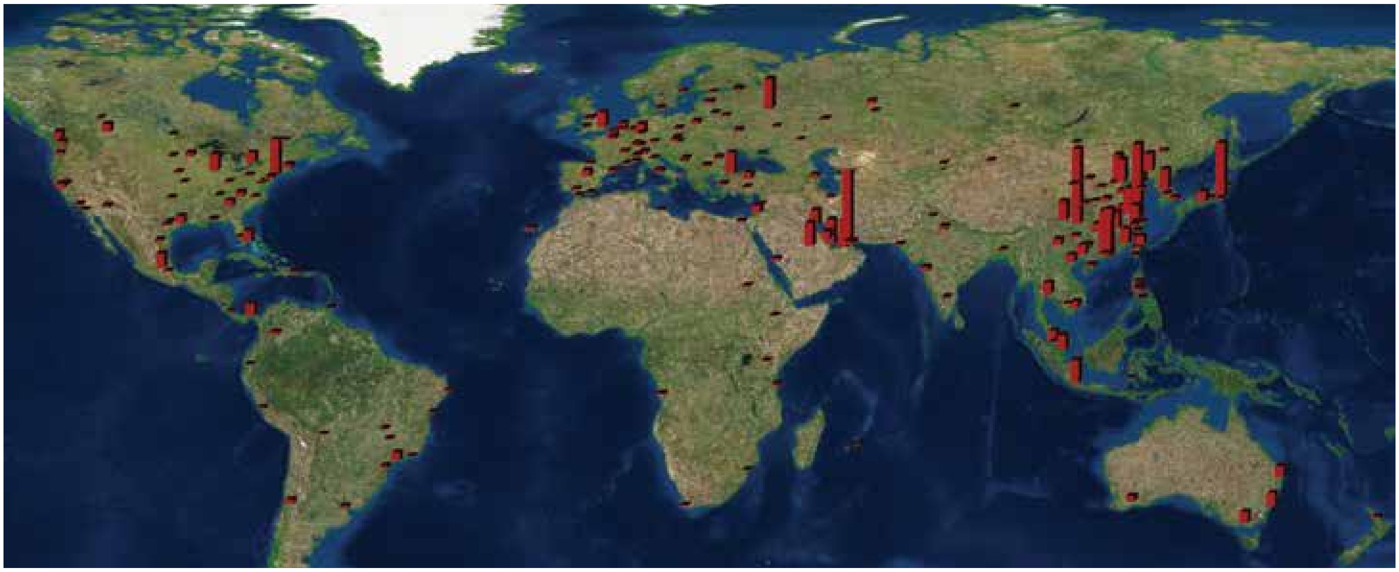

Figure 2. The development of new skyscrapers[1] between 2000 and 2015. Source: CTBUH & CBRE Research 2016.

this analysis the authors consider it principally as a causal factor. The larger the stream of profits in absolute terms from participating in a city's economy, the greater will be the capital deployed and the labor utilized to generate those profits. In other words, the stock of floor space in general, and skyscraper floor space in particular, adjusts to the level of GDP. In Figure 3 the authors show the univariate relationship between GDP and skyscraper floor space by means of a scatter diagram, and find a correlation of 0.64 (106

“Hypothesis: Four factors explain the quantum of space within skyscrapers: the GDP of the city, the land area of the city, the global connectivity of the city, and the presence of land-use regulations that place restrictions on individual building height.”

[1] In this research a skyscraper is defined as a tall office building higher than 100 meters. Only buildings of such height and with exclusively office use or at least a mixed use that includes offices are taken into account.

[2] Please note that the authors use a logarithmic scale to display the variables in all scatter diagram figures. GDP is in millions of US$.

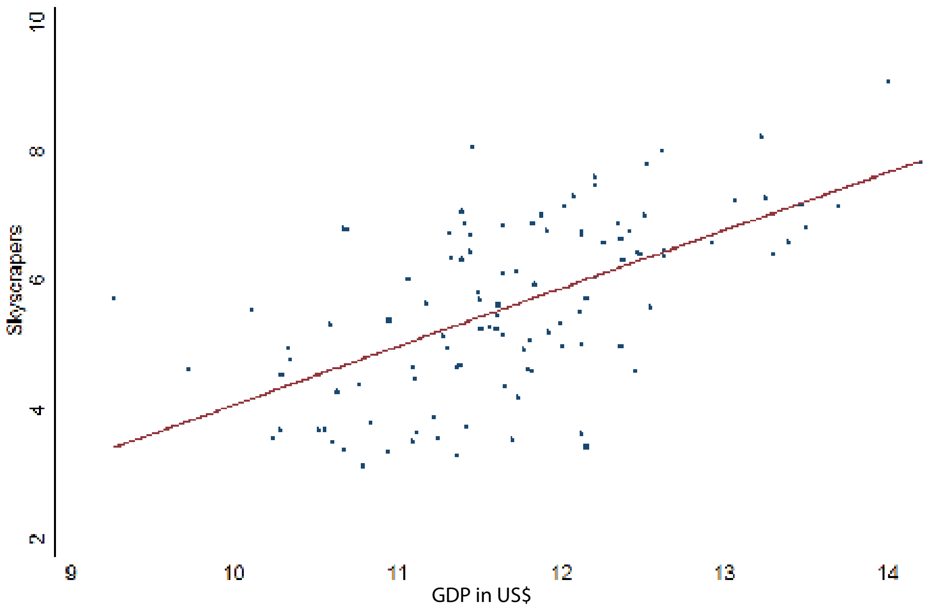

Figure 3. Skyscrapers[1] vs. city GDP. Source: CTBUH, OECD & Oxford Economics, CBRE Research 2016.

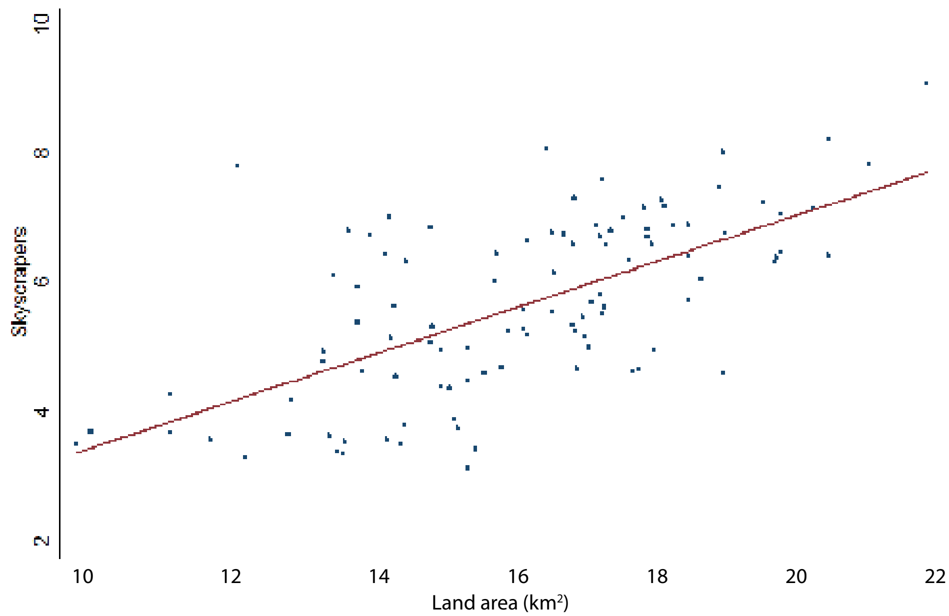

Figure 4. Skyscrapers[1] vs. land area. Source: CTBUH, Demographia, CBRE Research 2016.

“It is tempting to suggest that the recent rapid growth of emerging-market cities has created a desire for recognition that has created ‘skyscraper envy,’ which has led to wasteful overdevelopment. At this stage, the data do not confirm or deny this.”

cities observed).[2] The bigger the city in income terms, the greater the amount of floor space, on average, in skyscrapers.

The overall size of the city in geographical terms is also a key driver of skyscraper development. The mechanism here is more complex than "weight of money" in an economy. The larger the city in geographical terms, the greater, in general, will be the distance from the center to the periphery, and the greater will be the cost in terms of time and money to travel that distance. Thus, in larger cities, land at the center is more expensive relative to the periphery because of the premium paid for access. This is a well-known result in urban economics. In Figure 4, the authors see the relationship between both, which has a strong correlation of 0.68 (104 cities observed). Of course, there is correlation between land area and GDP, but these factors are disentangled in the multivariate analysis below.

The authors believe that one final economic factor is at work in the development of skyscrapers: the position of the city in the global hierarchy of cities. To investigate this relationship, the authors use data from the Globalization and World Cities (GAWC) Research Network, which records and scales the number of regional or headquarters operations of advanced producer services companies. The term used for the positioning of the city is "connectivity." The more global and regional headquarters functions a city contains, the greater that city's connectivity with, and influence within, the global economy. "Connectivity" based on the GAWC data is based on economic "reach" and is a hard measure of global city status. The correlation between skyscrapers and global connectivity is high, at 0.60 (see Figure 5). Connectivity is weakly correlated with land area and moderately correlated with GDP.

Finally, one "non-economic" factor at work in the development of skyscrapers is land-use planning. The authors believe that this factor is much more intense in Europe, due to the concern for the preservation of "heritage." Rather crudely therefore, in this model, a

	Coefficient	
GDP (log)	0.28	**
Land Area (log)	0.29	**
Global Connectivity (log)	1.12	***
Europe[6]	-1.17	***
Constant	-10.60	***
Adj. R-squared	0.67	
F-test	54.13	***
N	104	
Notes: All predictors are measured at city-level. ***, ** indicate significance at 1% and 5% level, respectively.		

Table 1. Regression estimates for predictors of the number of office skyscraper floors in cities.

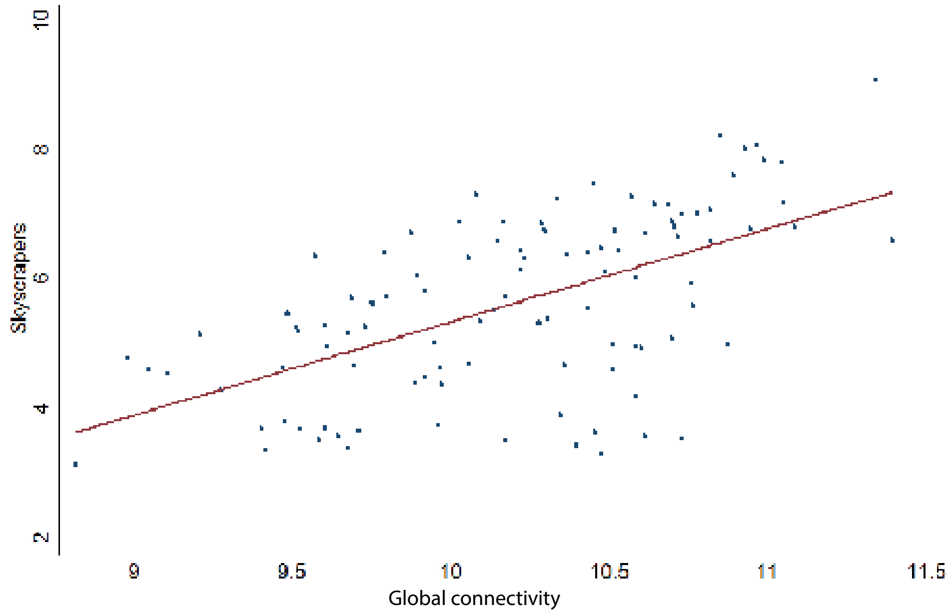

Figure 5. Skyscrapers[1] vs. connectivity. Source: CTBUH, GWAC, CBRE Research 2016.

dummy variable for presence of the city in Europe is included.

Results

Table 1 shows the results of the multivariate regression. The model explains 67% of the variance in the data.[3] To ensure that the authors' estimates are reliable, tests are conducted for heteroscedasticity[4] and multicollinearity.[5] These tests indicate that the model is unbiased and efficient. All of the variables are significant in the way the authors hypothesized. The two most important variables are the GAWC connectivity measure and the Europe dummy. The coefficients on GDP and land area are small and there is only a small impact on the adjusted R-Square if they are dropped from the model. The regression indicates that a 10% increase in connectivity is associated with an 11.2% increase in skyscraper floor space. Also, other factors being equal, European cities have on average 69% fewer skyscraper floors (in 100 meter+ office buildings) than cities elsewhere.

Finally, a 10% increase in GDP and land area leads to a 2.8% and 2.9% increase in skyscrapers, respectively.

Does this research mean that city size in term of land area or GDP are not important in the development of skyscrapers? No, but it does remind us that size and GDP are a function of economic relevance, which in turn is a function of location and productivity. The GAWC data, which measures the density of advanced producer services, is a better measure of the skill base and agglomeration effects that determine productivity. The situation is also likely to be dynamic, as skyscrapers attract businesses, which create agglomeration economies, which in turn generate productivity and the incentive to develop. With this in mind, the authors can't help thinking that Europe's lack of skyscrapers and its low trend rate of growth are somewhat interrelated, even if the heritage tourist industry is buoyant.

By considering the model's outliers (see Figure 7) the authors can also shed some light on cities with more or less skyscraper floor space, than the economic variables in the model predict. By and large, the positive outliers, that is, cities with more skyscraper floor space than predicted, are cities in emerging markets which, until recently, have experienced very rapid rates of growth.

One key source of emerging market dynamism is the growth of China: four of the positive outliers are in that country (Hong Kong, Shenzhen, Tianjin, and Guangzhou). Another seven cities are in emerging markets that have done very well due to the resource boom that accompanied China's growth and the period of very high oil prices (Dubai, Moscow, Doha, Abu Dhabi, Brisbane, Winnipeg, and Calgary). Other positive outliers are in finance-driven cities (Frankfurt and Basel) or other fast-growing emerging markets (Istanbul and Ankara).

It is tempting to suggest that the recent rapid growth of emerging-market cities has created a desire for recognition that has created "skyscraper envy," which has led to wasteful overdevelopment. At this stage, the data do not confirm or deny this. The

[3] Please note that a model without a dummy for Europe yields to a 10% lower R-square and lower overall (F-test) model fit.

[4] The authors test for heteroscedasticity by means of the Breusch-Pagan test. The Breusch-Pagan tests that the variance of the residuals is homogenous. In our case, the test supports the null hypothesis that the variance is homogeneous.

[5] The authors test for multicollinearity using the variation inflation factor (VIF). The VIF scores from our regression model indicate that there is no possible multicollinearity problem.

[6] Please note that the authors include a dummy variable for Europe and that the coefficient for Europe is relative to the rest of the world.

Skyscraper Development in New York, Shanghai, and Dubai from 2000 to 2015

Since 2000, a vast share of office skyscraper development has concentrated in cities and markets that have emerged in terms of global connectivity, such as those in the Middle East and Asia (see Figure 1). To put this at a city-level perspective, below are shown three highly connected cities: New York, Shanghai, and Dubai.

Each of these cities shows a different history in terms of its skyscraper supply and global connectivity. Consider first the skyscraper development from 2000 to 2015: 2,564 office skyscraper floors were added in Shanghai, 3,059 in Dubai, and 1,263 in New York. Although the smallest number of floors was added in New York, this city remains the world's skyscraper capital (in terms of number of buildings of 100 meters or greater) and a long-time established center of global business. Shanghai, by contrast, has over recent decades been emerging as a globally connected business center with sky-scraping ambitions. Recently, Dubai has also emerged as a city with numerous skyscraper developments, with the Burj Khalifa as the current world's tallest building. These different histories are reflected in how the floors added between 2000 and 2015 have impacted each city's floor supply since 2000: the data show supply increases of 1,999% and 547% in Dubai and Shanghai, respectively, against a 17% increase in New York's mature market.

Geographical patterns in these supply changes are illustrated in Figure 6 by the spatial density of floors in (100 m+) office skyscrapers. Comparison of the left panels show how, over 2000–2015, in New York floors have been added mainly within the middle and lower parts of Manhattan, resulting in densification of office land use. Shanghai, by contrast, shows a pattern of more dispersed development across the city's core (mid-panels). The right-hand side panels show how the supply of skyscraper floors in Dubai increased from sparse to a considerable supply. The situation in both emerging cities, Dubai and Shanghai, underline the lasting and rapid character of changes in skylines and urban patterns that can be brought about by global connectivity.

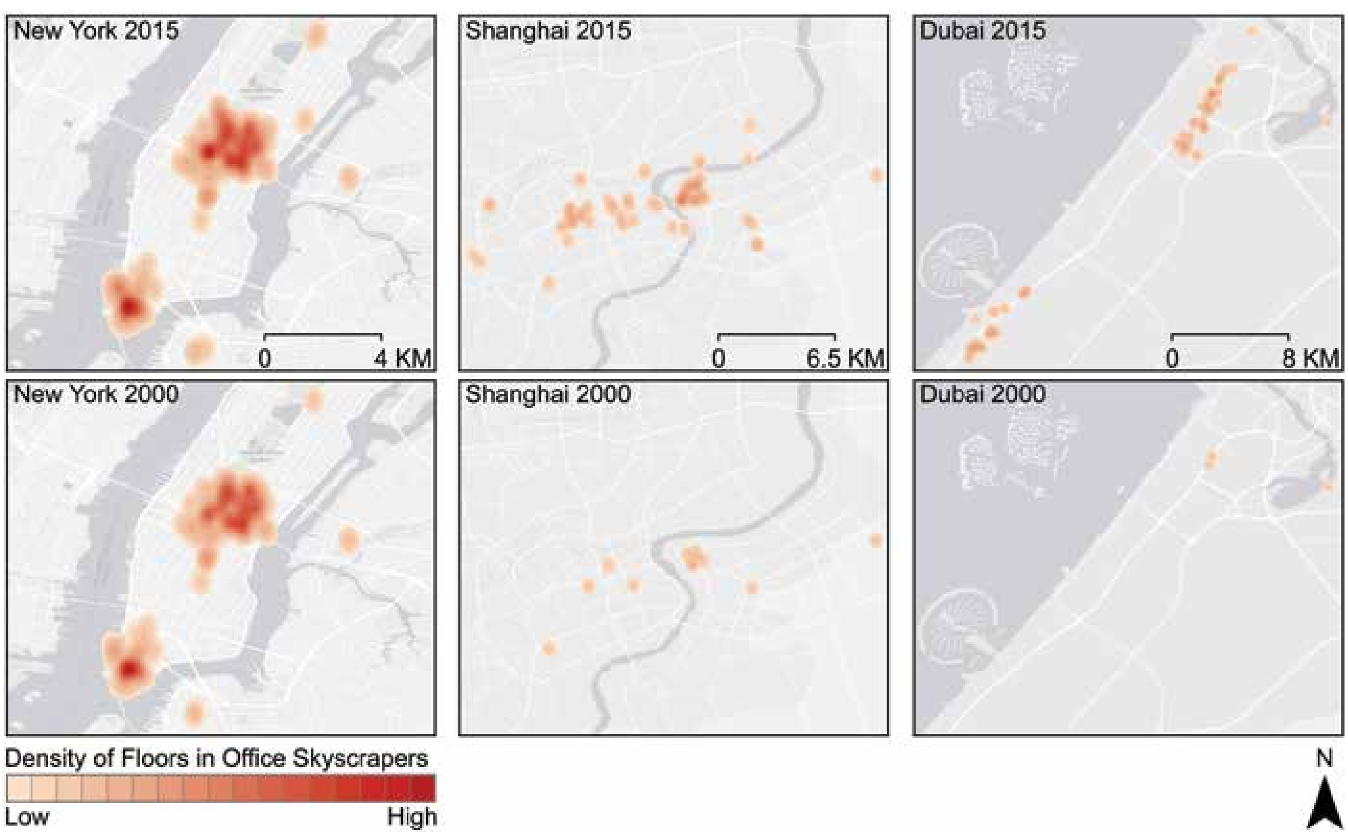

Figure 6. Skyscrapers[1] vs. connectivity. Source: CTBUH, GWAC, CBRE Research 2016.

argument that emerging-market cities have had to react very quickly to new economic conditions – including the influx of corporations from overseas and the fact that vertical development of floor space is a more efficient response than sprawl – is at least as good. The cities that have fewer skyscrapers than the model "predicts" include a number that have historic core areas (Milan, Munich, Amsterdam, and Rome), are relatively low-growth in nature (Adelaide, Ottawa, Cairo, and Buenos Aires), or may be somewhat vulnerable to earthquakes. However, underdevelopment is harder to explain than overdevelopment.

Another interesting perspective arises from the division of the sample into subsamples of buildings higher than 150, 200, and 250 meters. When this division is undertaken, the strength of the model fit is lower. This implies that especially tall skyscrapers are the result of mechanisms different from the ones that may be associated with "normal" skyscraper development. A supertall skyscraper of 300 meters or above, for instance, may be more a result of skyscraper competition than of economic fundamentals, as some have suggested (Michaelson 2014).

Conclusion

Skyscrapers are widely believed to be synonymous with a city's wealth and its global competitiveness. Hypotheses about the social and economic processes that lead to the development of skyscrapers are numerous, but empirical evidence is scarce. In this article, the authors uniquely looked at four factors; the GDP of the city, the land area of the city, the global connectivity of the city and the presence of land use regulations that place restrictions on individual building height for aesthetic or public safety reasons. All of these factors help to explain the quantum of space within skyscrapers in cities across the globe.

However, this study finds that a deep presence of advanced producer services, together with location outside of Europe, are the most important variables in explaining cross-sectional differences in the number of skyscraper floors (in buildings above 100 meters). As such, this study supports the hypotheses that more regional and global headquarters functions in a city leads to greater connectivity with, and influence within, the global economy. However, for supertall buildings, there might also be other, non-economic factors at work, which are omitted in this research. In future research, the authors will incorporate these factors and focus on different subsections to crystallize a deeper understanding of skyscrapers. ■

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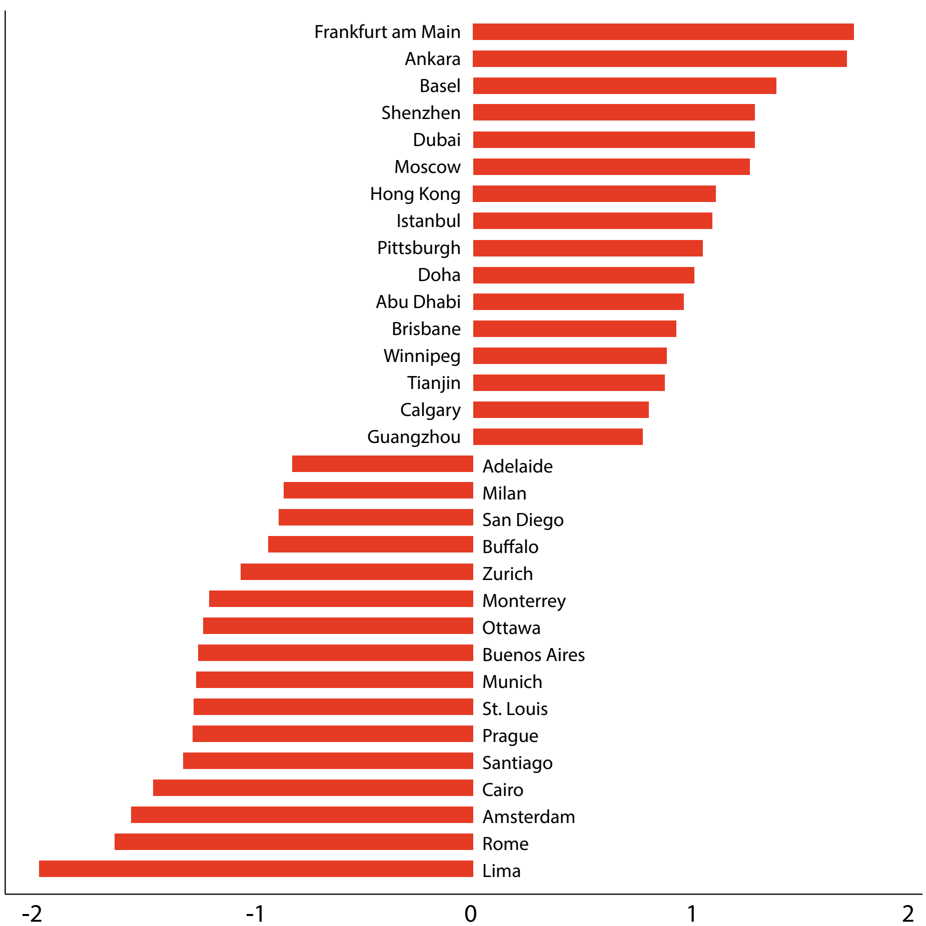

Figure 7. Diagram showing cities with lower actual skyscraper development than would be predicted (numbers less than zero) and more than would be predicted (greater than zero) by the authors' regression models.
Source: CTBUH, GWAC, CBRE Research 2016

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