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Author: Sofia Dermisi, Professor of Real Estate, University of Washington

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Global Cyclical Resurgence and Clustering of Office Skyscrapers

Sofia Dermisi
Professor of Real Estate

University of Washington,
Seattle, USA

Dr. Sofia Dermisi, is the Runstad Endowed Professor in Real Estate at the University of Washington. Dr. Dermisi holds a Master and Doctoral degrees from the Harvard Design School. She is also a certified LEED Green Associate. Dr. Dermisi's research agenda has focused on major downtown locations, with three areas of emphasis: sustainability, disasters and market analysis. Dr. Dermisi has earned many awards for excellence in her research and published more than twenty papers in peer reviewed academic journals. Dr. Dermisi received external grants from the National Science Foundation, Real Estate Research Institute, Illinois Department of Transportation and BOMA/Chicago.

Abstract

Skyscraper development has been linked with financial extremes; this paper explores this relationship by analyzing global construction trends for office skyscrapers with a height of at least 600ft, through GIS and econometric modeling. The spatial analysis provides evidence of clustering while the econometric results suggest that skyscraper height is 10.3% less among those commencing construction in Asia during a recession. A similar negative effect (11.1%) on height is experienced among structures with longer construction times in Europe and newer structures in the Middle East. In contrast, US skyscrapers completed during a recession are 9.9% taller compared to any other period.

Keywords: Cyclical Resurgence, Global Office Skyscrapers, Office Skyscrapers, Skyscraper clustering

Introduction

The link between skyscraper development and financial conditions/extremes has been explored by academics, professionals as well as media. Academically, this has been a topic of interest for a number of years and although construction techniques have evolved through time understanding the timing, reasons, location and implications behind the development of skyscrapers have not yet been fully understood. Grant (1996) and Lawrence (1999) were among the first to suggest a link between supertall buildings and impeding financial crises. Barr et al., (2015) suggest that "extreme height is a leading indicator of GDP". Height has also been linked to booming times in New York City (Barr 2012) as well as market fundamentals and builder's egos (Barr, (2010); Helsley and Strange (2008), Tauranac (1995)). Helsley and Strange (2008) offer a game theory approach to tall building construction and the developer attitudes. Thorton (2005) argues that extreme height is influenced by financial liquidity. However, Barr et al., (2011) found a lack of international relationship between skyscraper's height and business cycles. Beyond the academic exploration, professionals framed a link between skyscraper development and financial crisis in the form of the Barclays skyscraper index, which suggests the existence of a link between construction of the world's tallest buildings and impeding financial crises Lawrence (2012). Finally, media outlets (The Economist, 2015; Shaw, 2014; BBC, 2012; The Guardian, 2012; Reynolds, 2012) have been also have also suggested a possible link between super tall skyscraper development and financial crises in the past.

The aforementioned academic studies have focused on either a specific geographic area or a sample of super tall buildings worldwide. This paper provides a cross-sectional study of worldwide office skyscrapers with height of at least 600ft (183m), and assesses the spatial allocation of the various buildings while accounting for local key economic conditions. The inclusion of all office skyscrapers worldwide is critical, because historically the US has led the development of the skyscrapers, but in recent decades it has been dwarfed by the rise of emerging economies especially in Asia and in some part the Middle East. The financial liquidity in the latter two regions as well as the more relaxed regulatory environment have led to the exponential increase in skyscrapers especially in Asia and less in the Middle East. The data are analyzed with the application of difference methodologies to assess the spatial distribution of these skyscrapers in addition to the econometric modeling, offers a more holistic assessment of the skyscraper trends through time.

Data/Methodology

The paper examines the spatial distribution of existing office[1] buildings with a height of at least 600ft (183m) exploring the possible links to underlying economic conditions, while utilizing readily available economic variables. A selection of exclusively office skyscrapers rather than mixed use buildings was deliberate because of the homogeneity of these buildings, because the mix-use buildings can differ on their percentage distributions of the various uses and the information on these percentages is not readily available. Building specific information is obtained from a combination of sources, such as the Council of Tall Buildings and Urban Habitat skyscraper's database, Emporis.com and websites of the various skyscrapers. The specific building attributes collected include: building address, geocoding (longitude and latitude), height, gross square feet, construction start and completion dates, number of elevators and type of structural material. The skyscraper data were also complemented with economic data, which included all the recession periods from 1860 through 2011, GDP per capita and unemployment rate from the National Bureau of Economic Research (NBER), Bureau of Labor Statistics (BLS), World Bank, tradingeconomics.com and countries ministries.

The paper provides insights on skyscraper allocation and adoption, by exploring:[1]) the spatial distribution across countries/cities and 2) the effects of external and internal conditions on skyscraper heights.

The spatial distribution of these skyscrapers is assessed by identifying evolving patterns based on height and construction year by using Geographic Information Systems (GIS). Initially, the information was aggregated at the country level to determine a sufficient number of observations for further analysis. The data were then allocated to their respective cities to determine sufficient number of observations for a more in depth analysis at the lowest possible geographic level as well. Four cities were selected for additional analysis with at least 20 skyscraper buildings each. Each building was placed within their respective cities based on their coordinates and a directional distribution of construction activity was determined for Chicago, New York, Hong Kong and Shanghai. The directional distribution was selected as a representation and assessment tool of the spatial concentration or disbursement as well as the direction new construction occurred through various time periods buildings were built, providing insight on potential underlying development patterns through time. In addition, hot spot analysis is carried out for cities with at least 30[2] skyscrapers. This type of analysis allows the identification of spatial clusters of buildings with similar characteristics and in close proximity.

This spatial analysis is complemented by assessing the effect of readily available economic factors on building height in feet. A fixed effect regression model is used to control for the countries while clustering by the year the buildings were completed and weighted by the gross building area (Equation 1).

$$\ln(skyscraper\ height_i) = \alpha + \beta_1 Pr_i + \beta_2 Ec_i + \eta_i + c_i + \varepsilon_i$$

Where:

- skyscraper height: is the height of the building in feet
- i: takes values from 1 through n representing each of the skyscrapers among 4 regions (Asia, Europe, Middle East and US)
- Pr: is an umbrella variable which includes the following variables - completion year, number of elevators, the difference between construction finish- start, and dummy variables for recessions (1 for a recession year or otherwise 0) and type of structural material
- Ec: is another umbrella variable, which includes overall economic conditions such as the GDP per capita and unemployment rate
- η: reflects the country specific characteristics which are time invariant.
- c: clustering of skyscraper by completion year.

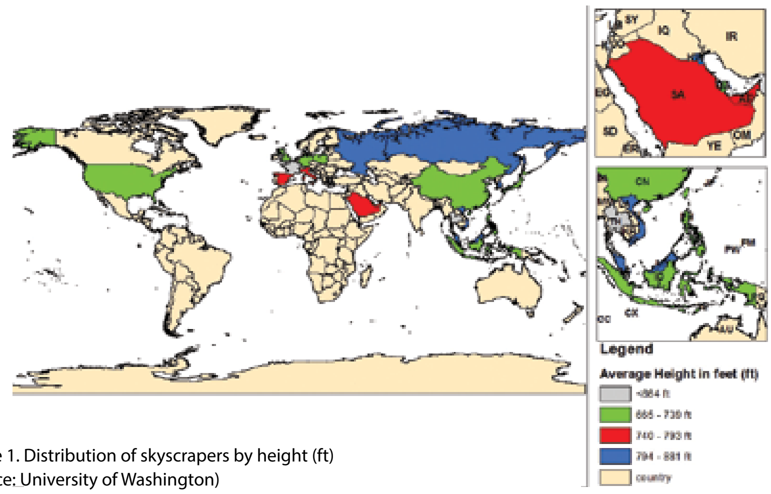

Figure 1. Distribution of skyscrapers by height (ft)
(Source: University of Washington)

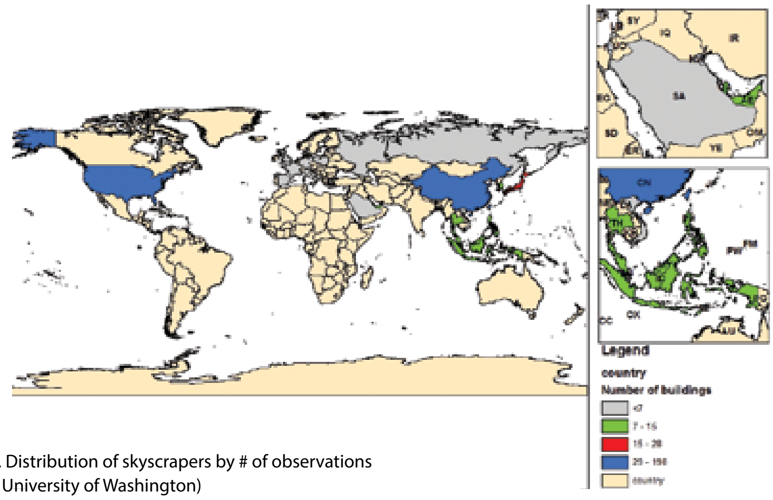

Figure 2. Distribution of skyscrapers by # of observations
(Source: University of Washington)

1. The data include only office buildings (with minor retail component) and not mixed-use buildings constructed by 2013.
2. At least 30 observations are required for the hot spot analysis.

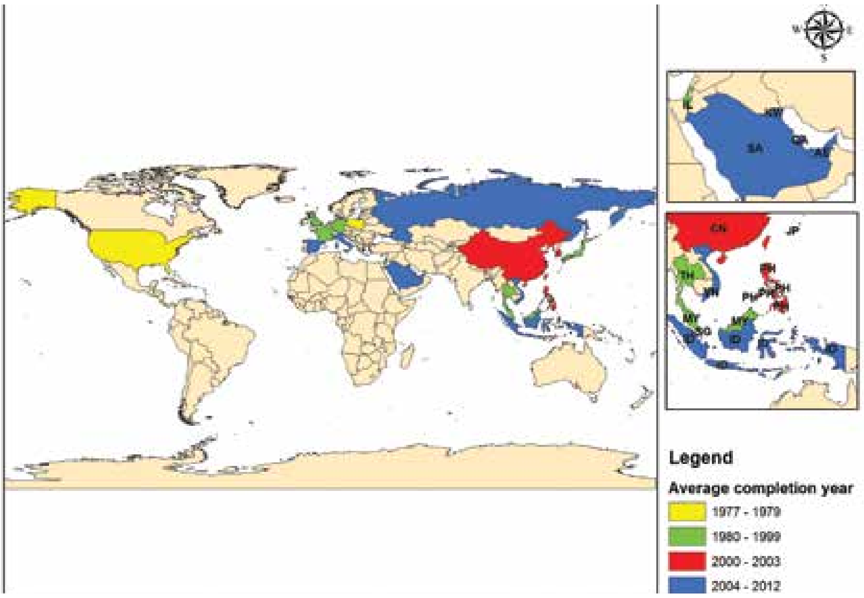

Figure 3. Distribution of skyscrapers by average completion year (Source: University of Washington)

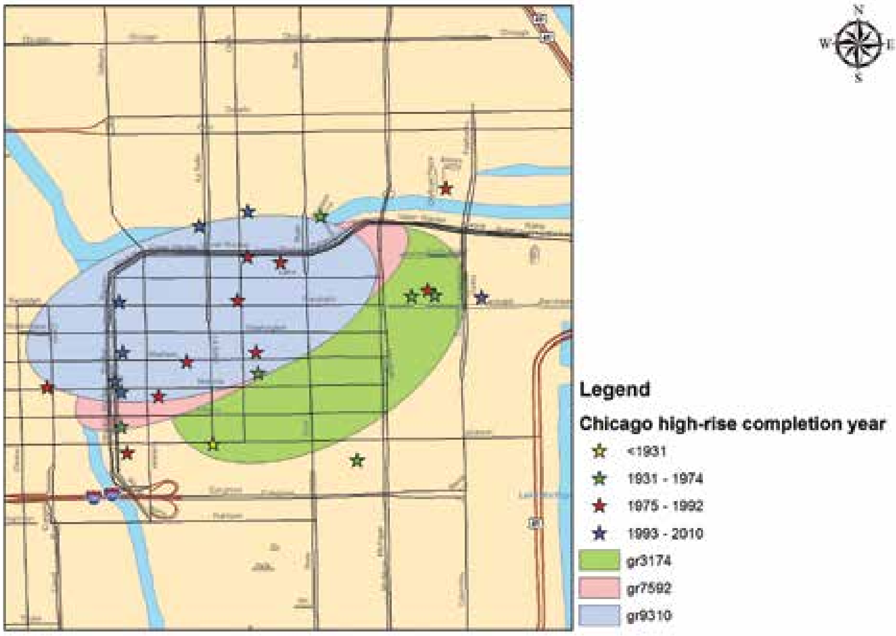

Figure 4. Directional distribution of skyscrapers in Chicago (Source: University of Washington)

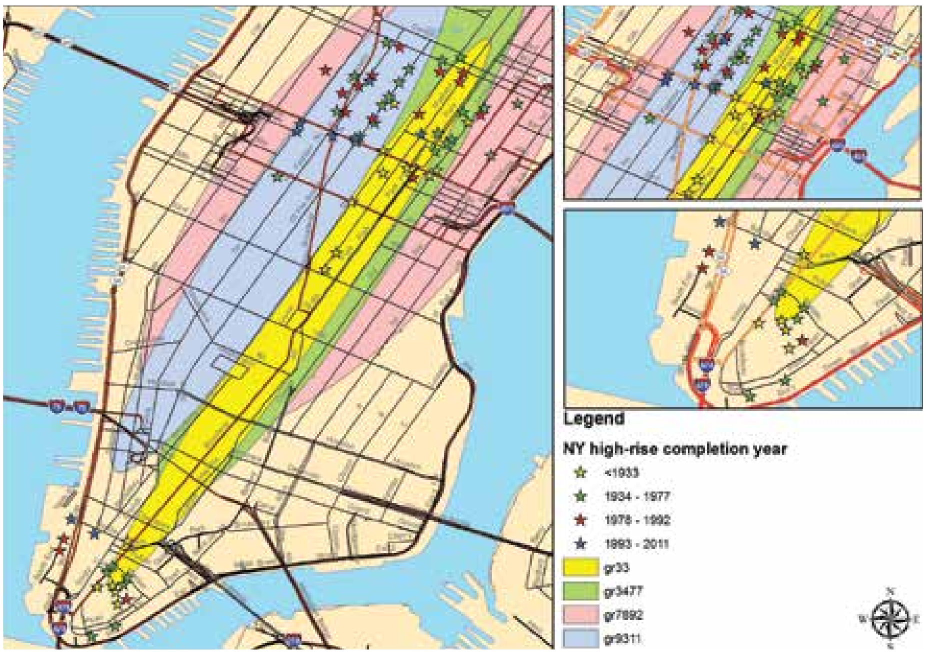

Figure 4. Directional distribution of skyscrapers in New York (Source: University of Washington)

Results

The initial mapping of exclusively office rather than mixed-use building skyscraper distributions, based on height, number of observations, and year of completion indicates that buildings in the Middle East and Europe/Russia are on average taller and newer compared to the US and China. However, this result is skewed because of the limited number of tall buildings (7 or less) among these countries when compared to the US and China (Fig. 1 and 2). We also observe the aged building stock in the US versus other countries, compared to the Middle East, Asia and Russia which are expanding their number of skyscrapers more recently (Fig. 3). Among the factors influencing the lack of new skyscraper development in the US in contrast to the trends of the other regions are: a) the absence of significant infill sites in downtown areas, which are the locations usually selected for the development of such buildings, b) land assembly might be required in a dense downtown area, which can either prevent or delay further developments, c) the significant time and cost associated with the demolition of a building, which increases the exposure risk to the developer, d) significant regulatory environment and long approval processes, e) depending on the height and complexity of the structure the possibility of a multi-layer financing might be required, therefore delaying the construction of such buildings and f) community opposition due to increased traffic as well as reasons of open spaces etc.

Some preliminary descriptive statistics assessment of the data suggest that 82.3% of office skyscrapers are across three regions (Asia, Europe and Middle East), however the highest concentration of skyscrapers is in the US (198) rapidly followed by China (185). Although the total number of skyscrapers between the US and China does not indicate a significant difference, however, the first skyscraper in the database was built in the US in 1909 and in China in 1980. The exponential increase of skyscrapers in China over the last 33 years compared to the US can be attributed to factors such as financial liquidity, availability of space, developer ego and significant government support including less regulatory environment, which fuelled the booming of skyscrapers.

Utilizing GIS the directional distribution was estimated among cities within a min number of observations in both the US (Chicago and New York) and China (Hong Kong and Shanghai). The results suggest shifts in construction activity through the decades as well an outward expansion even beyond the high density areas especially in Asia (Fig. 4 -6). Two key reasons for expansion in a dense downtown area are: a) the lack of vacant land- which requires developers to demolish an existing structure, therefore adding significantly to the construction budget or b) owner reluctance to sell their site hoping for future improved offers on their land. More specifically, the results suggest that skyscrapers in Chicago located closer to the major commuter mass transit station (Union station). New York has two main areas of concentration, midtown and downtown Manhattan, which have remained the same through the years because of the residential component in the middle as well as the commuter train stations which are located in close proximity to the two locations. The China data for both Hog Kong and Shanghai indicate that skyscrapers are building beyond the urban core.

Among the 540 exclusive office skyscrapers with 600 ft or more, 50.3% are located in Asia and 38.9% in the US (Table 1). The descriptive statistics of Table 1 suggest that on average the newest skyscrapers have been constructed in the Middle East, followed by Asia while the height of US and Asia buildings are comparable. Surprisingly, Middle East buildings are on average the tallest ones with their number of stories slightly below the US. The Middle East is another interesting case since the first skyscraper with at least 600ft was built in 1999. The financial liquidity since 1999, as well as the interest in building massive buildings in a less regulated market has led to the significant increase of such structures not only in the Middle East, but in China as well. Within Asia, 64% of buildings are located in China, while Europe has a level distribution among Germany, U.K., France and Spain. Overall, seven countries (US, China, Japan, Singapore, Malaysia, UAE and S. Korea) have at least 10 skyscrapers. In the Middle East, 37.5% are located in UAE and 28.1% in Qatar. Shifting the focus to US cities, the highest office skyscraper density is observed in New York City (67 buildings) followed by Chicago (24), while in Asia, Shanghai (44 buildings) has the highest concentration followed by Hong Kong (31), Shenzhen (25) and Tokyo (24). (more than 20 buildings; group reflects the age a building was constructed based on a specified group[3], eg. gr 3172 indicates that the buildings within this group were built between 1931-1972 etc.)

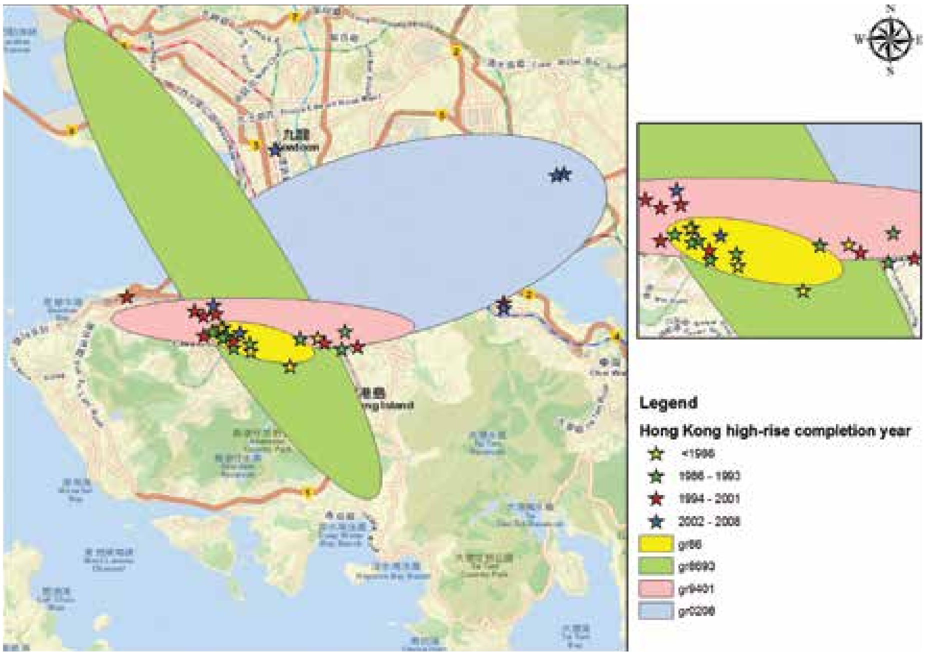

Figure 6. Directional distribution of skyscrapers in Hong Kong (Source: University of Washington)

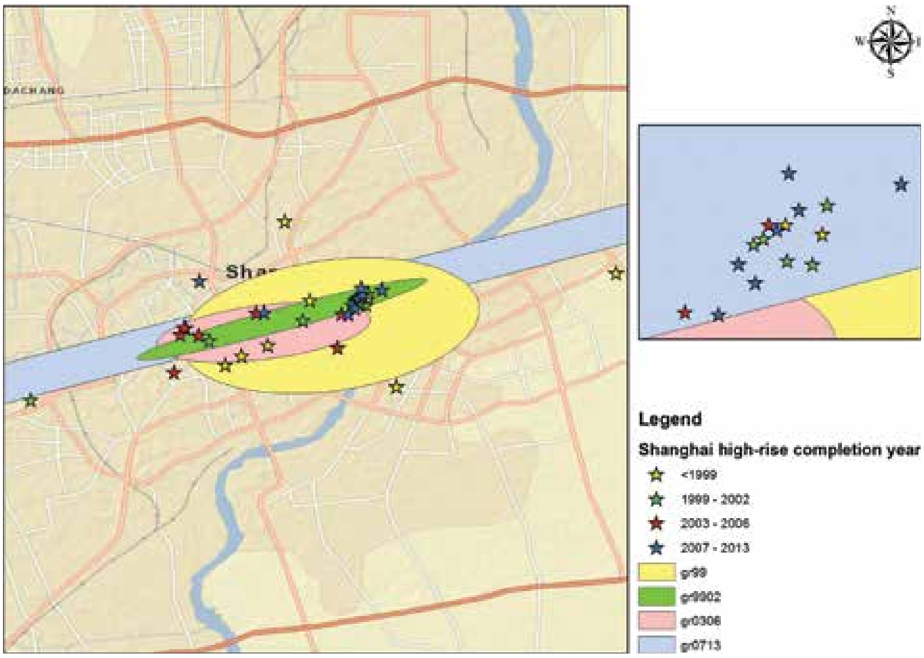

Figure 7. Directional distribution of skyscrapers in Shanghai (Source: University of Washington)

Regions	observ.	Year completed		Height (ft)		# floors		Gross square feet	
		mean	standard dev.	mean	standard dev.	mean	standard dev.	mean	standard dev.
Asia	256	2002	8	732.81	152.79	48.59	10.27	1,245,045	747,328
Europe	22	1997	15	719.77	86.91	48.68	8.15	962,703	372,781
Middle East	33	2009	3	776.55	181.65	49.15	11.18	1,033,645	612,813
US	198	1980	20	730.26	130.98	51.54	9.91	1,394,204	558,096

Table 1. Overall descriptive statistics (Source: University of Washington)

[3]: The construction age groups were generated based on the construction year frequency.

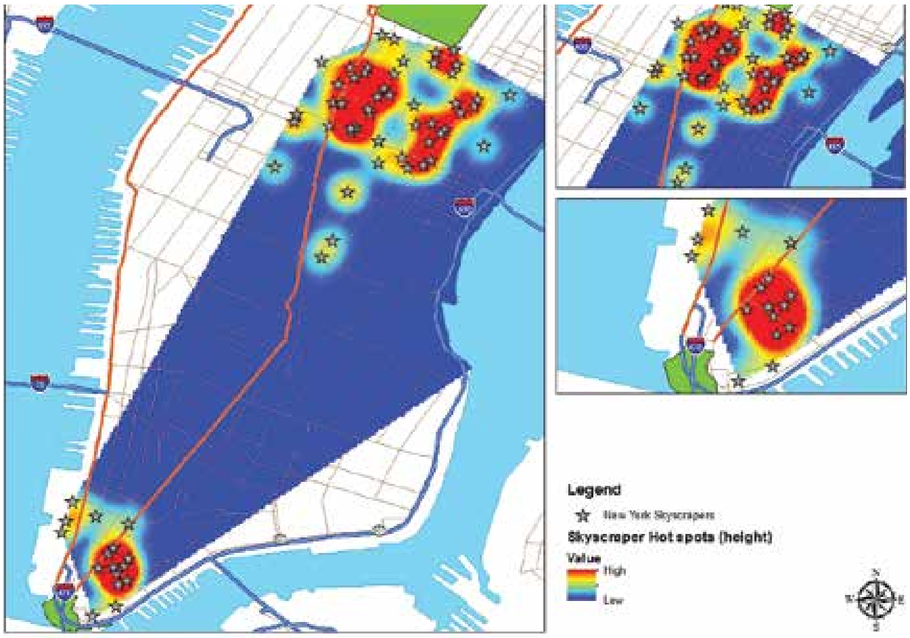

Figure 8. New York hot spots (height) (Source: University of Washington)

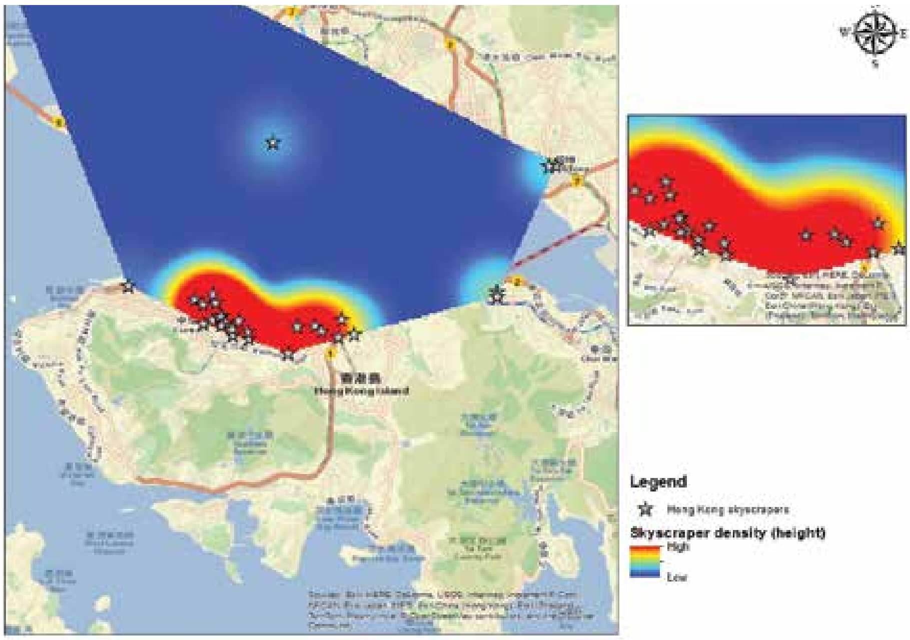

Figure 9.Hong Kong hot spots (height) (Source: University of Washington)

The hot spot analysis focused on three[4] cities with at least 30 skyscrapers (fig. 8-10). The results suggest some distinct clusters in all cases based on the skyscraper height and their proximity to each other. The existence of significant clustering is indicative of agglomeration economies among buildings with similar heights. Among the key reasons for this clustering is usually the access to transportation options and the pursuit of a tenant base with a preference in locating in certain areas. Additionally, the clustering can be caused by the absence of available lots, which can accommodate developer requirements. Lot scarcity and land assembly issues have been examined by Willis (1995). The results of this study indicate the existence of three distinct clusters are defined in New York City (NYC), with two being in midtown Manhattan and the other in downtown. Comparing NYC with Hong Kong and Shanghai, only Shanghai seems to share a similar pattern, because of the significant development in Pudong, which was led by the pro-development government push in the area as well as the availability of land. The pro-development attitudes and the facilitation of expedited permitting for certain targeted areas can lead these areas to significant success with additional infill development occurring, such as the case of Pudong. The absence of differentiating clusters in the case of Hong Kong suggests a more homogeneous market with the similar levels of agglomeration. Among the distinct characteristics of this city is the confined core because of the surrounding mountains and sea as well as the substantial density, which resembles New York. However, the result is still surprising compared to the other two cities. Rosenthal and Strange, 2008 have offered some insights on the influence of geological conditions on agglomeration.

Shifting the focus to the effect of internal and external conditions on skyscraper height, the results from the econometric comparison among the four regions indicates a less consistent picture although some similarities exist between Asia and the US (Table 2). The results suggest that office skyscrapers in Asia which commenced construction during a recession are 10.3% shorter than those constructed at any other period in time. This result is indicative of a market which influences the type of development either because the developer cannot obtain the funds for a larger structure or because of a cautionary reaction to a market contraction. The negative influence of the recession is more pronounced in the Middle East, where the height is 42.4% less, possibly caused by the limited number of observations and the construction activity which took place close to recessionary periods. Additionally, skyscrapers which were completed during a recession in the US are 9.9% taller than buildings completed any other time. A skyscraper of the size studied will require at least 2 years of construction and therefore the real estate and economic conditions may be very different from the construction announcement through the delivery, with the developer assessing the risks and rewards before proceeding in the project construction. This unexpected positive influence of the recessions on building height can be cause by: a) a missed real estate cycle or b) developers capitalization on the recession by achieving improved labor and material cost and delivering towards the end of the recession. Structural materials (composite, steel and concrete) have a positive effect on height for both Asia and the US. Composite structures command higher building heights in Asia by 30.8%, while steel structures are 16% and concrete 13.7%. In the US, composite structures are 11.1% taller, followed by concrete 10.6% and steel by 4.4%. Although the structural materials have a positive effect on building height in both Asia and the US the significant differentiation within the composite structures can be attributed to the construction timeframe of the both regions. Buildings in Asia are constructed on average 22 years after the US structures, with

4. GIS hot-spot analysis requires 30 observations and only three cities qualified for the more specific analysis.

significantly different construction techniques.

An unexpected effect experienced in the US data is the positive influence of the unemployment rate on skyscraper height, which can be justified by developers trying to capitalize on the lower construction costs by adding height and profiting upon the delivery of the structure during the market correction. The results suggest that a 1% increase in unemployment is associated with a 13.7% in building height. Additional results of interest suggest that longer construction times (start-to-completion) are associated with shorter skyscrapers in Europe by 11.1%. Based on Table 1 building heights in Europe are on average the shortest (719ft) with the various countries being highly regulated and bureaucratic, which can cause as well as prevent construction activity. Any project delays can be addressed by the developer creatively by focusing on value engineering of the project and the possible decrease in height which can expedite the delivery of the structure. Concrete as well as composite structures have a negative influence on building height by 39% and 17.5% respectively. European buildings are on average the second oldest beyond the US and considering the size of the dataset (only 21 observations) the results should be considered with caution. Similar is the case for the Middle East model, because of the size of the dataset. The Middle East column indicates that newer structures in the Middle East are shorter than older by 10.4%. This might be cause because of the construction timing boom of this region which is close and during the recession periods.

In their explanation all dummy variables are transformed (1-ecoeficient)

Conclusions

The analysis of office skyscrapers of at least 600ft worldwide has led to some important findings regarding their spatial distribution and factors influencing their location. The results suggest the existence of infill development in dense downtown's as well as expansion beyond expectations in downtowns especially in Asia. The skyscraper footprint is largest in Asia, which concentrates 50.3%, followed by the US (38.9%) and it was achieved in a very short period of time. Europe and the Middle East have a much smaller share, with the Middle East however continuously increasing the number of skyscrapers, while Europe's stock is more confined due to the strict regulatory environment and the significant

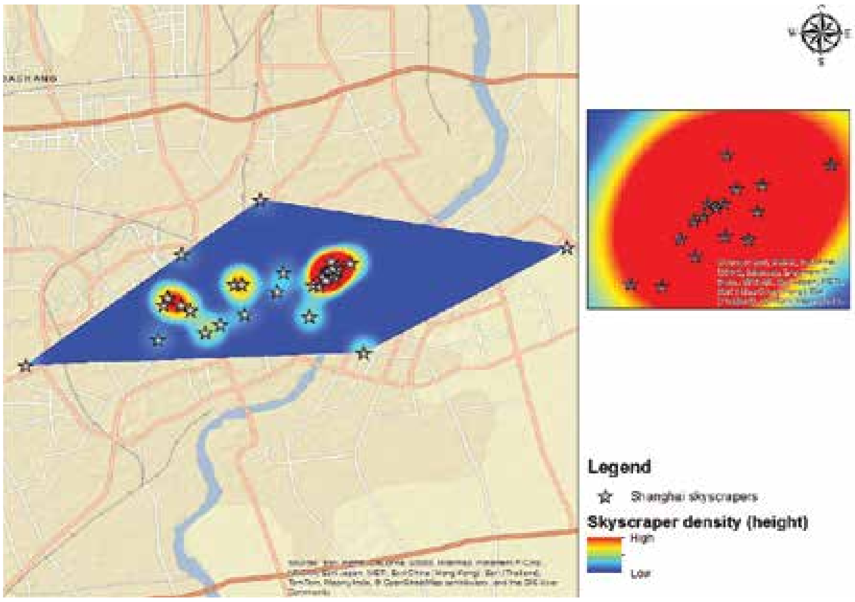

Figure 7. Shanghai hot spots (height) (Source: University of Washington)

	Asia	US	Europe	Middle East
Completion year				-0.099*
				-2.52
Number of elevators		0.00652***	6.120E-05	0.0176***
		6.74	0.01	6.78
Recession - - constr. Start	-0.0982**	0.01	-0.13	-0.354*
	-2.80	0.41	-1.03	-2.62
Recession - - constr. Finish	-4.57E-03	0.0946*	0.06	0.17
	-0.18	3.92	0.87	0.93
Construction finish-start (years)	0.01	0.01	-0.105*	0.05
	0.75	1.03	-2.19	0.65
Composite structure	0.269***	0.106***	-0.162*	0.09
	5.43	4.33	-2.46	.50
Steel structure	0.149***	0.0430*		
	3.64	2.16		
Concrete structure	0.129**	0.101*	-0.330**	0.39
	3.44	2.12	-3.28	1.34
GDP - constr. Start	-3.380E-06	1.940E-06	1.800E-05	-0.000157*
	-1.34	1.15	1.95	-2.66
ln(unemployment rate)	-0.03	0.129**	-0.26	-0.06
	-0.63	3.38	-2.13	-0.99
Constant	6.42	5.09	6.45	6.37
Completion Year Clusters	32	55	14	8
Countries-absorbed	10		7	6
N	211	193	21	21
Adj. R^2	30.60%	45.20%	63.20%	82.80%
vif	3.22	4.15	3.02	2.88

Table 2. Fixed-effects results (Source: University of Washington)

scarcity of prominent locations. Assessing the directional distribution of skyscrapers through time for four cities (Chicago, New York, Hong Kong and Shanghai), indicated the existence of differentiating patterns, with mass transit location being key in attracting tall buildings and the expansion of this trends throughout the years. Complementing this analysis was a hot-spot analysis of building heights in combination with their location among three out of the four cities (except Chicago). The results indicated the existence of distinct clusters in the cases of New York and Shanghai. Shifting to the econometric modeling results they offer additional insight on the effect of various external and internal factors on skyscraper height. An important result is that the height of skyscrapers is affected negatively by recessions during their starting phase in Asia, longer construction times in Europe and certain types of material (composite and concrete) in Europe also share the same effect. In contrast, skyscraper height increases with the presence of certain material (more with composite and steel vs. concrete) for Asia with similar trends for the US.

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