Skyscraper Height and the Business Cycle: International Time Series Evidence*

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Abstract

This paper is the first to rigorously test how height and output co-move. Because builders can use their buildings for non-rational or non-pecuniary gains, it is widely believed that (a) the most severe forms of height competition occur near the business cycle peaks and (b) that extreme height are examples of developers "gone wild." We find virtually no support for either of these popularly held claims. First we look at both the announcement and completion dates for record breaking buildings and find there is very little correlation with the business cycle. Second, cointegration and Granger causality tests show that height and output are cointegrated and that height does not Granger cause output. These results are robust for the United States, Canada, China and Hong Kong.

Key words: skyscraper height, business cycle, Granger causality, cointegration.

JEL Classification: E3, N1, R33

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1 Introduction

Since about 1885 the technological constraints to building height have essentially been eliminated, and the decision about how tall to build has been made based on economic, advertising, emotional and strategic considerations. One World Trade Center (the Freedom Tower), for example, demonstrates the emotional and strategic nature of height. At 1776 feet, this height was chosen to both be the tallest in U.S. and represent the political strength of the American republic.[1]

It has also been noted that bursts of extreme height appear in predictable locations within the business cycle (Thorton, 2005; Lawrence, 1999). One part of this discussion is that the world's tallest buildings seem to come online during recessions. For instance the Burj Khalifa, roughly one-half mile tall, opened in January 2010, amidst one of the worst downturns since the Great Depression.[2] More broadly, it is believed that extreme height can be used as predictor of output. A typical piece in the media is a recent CNN blog post, "China Skyscraper Boom Portend a Property Crash? (Voigt, 2011).

The media have also noted that the recent construction booms in Dubai and China (and in the 1920s in the U.S.) are examples of builders "gone wild"; the implication is that economic factors play only a small role in the height decision and that "irrational exuberance" can help explain the skylines around the world (Economist, 2006).

The aim of this work is to investigate the relationship between extreme building height and the business cycle. Despite the widespread interest in building height by the media, architectural historians and the public at large, no empirical work has explored how height and the business cycle actually comove. As implied above there are two elements to the conventional wisdom: (1) height is a leading indicator of the business cycle and (2) that during boom times, height decisions are not rational, and bear almost no relationship to

[1] More broadly the attack on the Twin Towers on September 11, 2001 illustrates the emotional and symbolic nature of skyscrapers, as the terrorists chose to destroy the tallest buildings in the city.

[2] Another is example is a speech given by the architect, Lawrence Nield, who claims that height is a leading indicator. This speech can be found at: http://www.youtube.com/watch?v=xPjF__wCnks

output.

We focus on building height, rather than some other building measures because of the economic importance of height, *per se*. Skyscraper height is the most visible component of a city's skyline (and perhaps *the* defining measure of a skyscraper, itself) and it is arguably the most discussed aspect of skyscrapers by the public at large and by scholars in other disciplines. Future work can explore other dimensions of skyscrapers such as their density or the size of their footprints, but this work aims to test some widely discussed hypotheses about their heights during the business cycle.

We first provide two versions of a simple model of the height decision–one with profit maximization and one that includes height competition. The model gives hypotheses about the relationship between height and output. Then we turn to the data to test the models. First we look at record breaking height. If record breakers are leading indicators of recessions, then we would expect to see a strong pattern between either their announcement dates or their opening dates within the cycle. However, we find no such pattern.

Second we estimate vector autoregressions (VARs) for the annual times series of the tallest building completed in a nation each year and real per capita GDP; and then we conduct Granger casualty and co-integration tests. We perform this analysis for the United States, Canada, China and Hong Kong. We find that in all of these countries real per capita GDP and height are co-integrated; and there is unidirectional causality from GDP to height (and no causality from height to GDP). These findings strongly suggest that (1) height is not a useful predictor of the business cycle and (2) that, though, non-rational or non-pecuniary height may exist in the marketplace, over the long run, height does not deviate from the underlying economic fundamentals. These findings are robust across countries.

The paper proceeds as follows. The next section offers a brief review of the relevant literature. After that we present the model. Then we investigate the timing of world record breaking skyscrapers within the business cycle. Next we present results from vector autoregressions. Finally the last section offers some concluding remarks.

1.1 Related Literature

There are only a handful of papers within economics on skyscrapers and the determinants of extreme height; the field remains under-developed. Thorton (2005) views extreme height as a result of rapid growth in the supply of money. Helsley and Strange (2008) model record-breaking height as a contest of egos. Clark and Kingston (1929) suggest that extreme height is a rational response to high land values. Barr (forthcoming) finds evidence that builders engage in height competition during boom times in New York City at the building level, but this result does not aggregate up to the market as a whole (Barr, 2010).

Within the real estate literature there are several papers studying the time series of macroeconomic and commercial real estate variables. For example, Green (1997) investigates a vector autoregression (VAR) of gross domestic product and measures of real estate investment. He finds that non-residential investment does not cause GDP, but is caused by GDP. McCue and Kling (1994) explore the relationship between the macroeconomy and real estate returns and find that output directly affects real estate returns. Our findings on skyscraper height are consistent with these works since we find that skyscraper height does not Granger cause GDP, but is caused by GDP.

2 A Simple Model

2.1 The Profit Maximizing Builder

Here we provide a simple model which we test below using international data. This is a simplified version of the model given in Barr (2010). A builder who intends to build a skyscraper will have the following profit function

$$\pi_t\left(H_{t-n}\right) = E_{t-n}P_tH_{t-n} - \frac{C_{t-n}}{2}H_{t-n}^2 - L_{t-n},$$

where $E_{t-n}P_t$ is the expected per-floor value of height. Since there are construction lags, the builder will not start earning rent until period t, given a decision about how tall to build at time $t-n$. H_{t-n} is the chosen height and $\left(C_{t-n}/2\right)H_{t-n}^2$ are the construction costs associated with building of height H_{t-n}, assumed to be increasing at an increasing rate (Barr, 2010). L is the fixed cost of land (assume all plots are normalized to one unit). As is common in the real estate literature (Wheaton, 1999; McDonald, 2002), we assume that builders use the current price for the expected price, $E_{t-n}P_t = P_{t-n}$.[3]

[3] Here we use a "myopic" rule for price formation. As Wheaton (1999) discusses rational expectations price formation is generally not consistent with office building construction patterns. However, our interest here is not in modeling cyclical behavior based on price

In the absence of any strategic interaction or ego considerations, profit maximization would yield an "optimal" height, given by

$$H^*_{t-n} = \frac{P_{t-n}}{C_{t-n}} \equiv Y_{t-n},$$

where Y_{t-n} is a measure of income, since it the value-added from the project. However, since there are lags in construction, we can assume that builders can make marginal adjustments to the heights of their buildings as new information is revealed so that the completed (observed) height, H_t is given by

$$H_t = H^*_{t-n} + \beta_{n+1}\Delta Y_{t-n+1} + ... + \beta_1 Y_{t-1},$$

where $\left|\beta_j\right| \leq 1$. Since builders have to pay some adjustment costs, we assume they can not fully adjust the heights as incomes change. Take the case where $n = 2$, this gives a height equation of[4]

$$\begin{aligned} H_t &= Y_{t-2} + \beta_1 \Delta Y_{t-1}. \\ &= \beta_1 Y_{t-1} + (1 - \beta_1) Y_{t-2}. \end{aligned}$$

In short, if builders maximize profits from construction then heights will be a linear function of net income; this is to say, we would expect to see an "integrated" relationship between the two and that lags of income are positively related to observed heights.

2.2 The Ego Builder[5]

Now let's say that builders are in competition with each other because they are concerned with their relative position in the height hierarchy. For simplicity, assume a utility function for a developer is given by

$$U(H_{t-n}) = \pi(H_{t-n}) + \left[\varepsilon H^r_{t-n}\right] H_{t-n},$$

formation but rather on modeling the relationship between income and height.

[4]Barr (2010) shows that two years is the average time between when a height decision is made and when a building is completed in New York City.

[5]Note that we use the term "ego" as shorthand for all the reasons builders may have to build taller than otherwise. This may include actual ego-based needs or advertising considerations.

where $\pi(H)$ is the profit from the project, H^r is the height of a rival building, which we assume has already been completed, and thus is taken as given. This is to say, we don't consider a simultaneous game (such as in Helsley and Strange, 2008), but for simplicity we assume that a builder takes a rival's height as fixed and then decides a height for his own building based on this. εH^r represents the "ego boost" from adding height relative to the rival's building, where $\varepsilon > 0$ is a fixed parameter, which is the weight a builder will give to a rival's building.

Maximizing utility at time $t-n$, gives

$$H^e_{t-n} = \frac{P_{t-n} + \varepsilon H^r_{t-n}}{C_{t-n}} = H^*_t + \frac{\varepsilon}{C_{t-n}} H^r_{t-n} \equiv Y_{t-n} + \frac{\varepsilon}{C_{t-n}} H^r_{t-n},$$

where H^e_{t-n} is the "ego" height. That is, the height decision is function of the profit maximizing height plus some additional component, which is a function of the rival's height. Thus builders are willing to dissipate some of their profits to engage in competition, and the constructed buildings are economically "too tall."

Taking the case, again, where $n = 2$ and that the completed building is equal to the chosen height plus some marginal adjustments gives:

$$H_t = \beta_1 Y_{t-1} + (1 - \beta_1) Y_{t-2} + \frac{\varepsilon}{C_{t-n}} H^r_{t-2}.$$

Note that if a builder is concerned about his place in the height hierarchy, height and income are no long "integrated" since the difference between the height and income is not constant. That is to say, in this case, height and income would be expected to move apart over time. Since builders are adding extra height to compete, then we expect height to rise faster than incomes. Also over time, we would also expect C_{t-n} to be diminishing due to technological change, thus presumably increasing the "wedge" between income and height.

2.2.1 Extreme Height

Because of the lags in construction, during boom times, builders may find that demand for space is rising faster than supply and thus the (expected) income from construction is increasing quite rapidly. During these boom periods, a builder might be willing to dissipate all of his profits to beat the current world record holder. In this case he would chose a height that sets his utility equal to zero:

$$U\left(H_{t-n}\right) = P_{t-n}H_{t-n} - \frac{1}{2}C_{t-n}H_{t-n}^{2} + \left[\varepsilon H_{t-n}^{r}\right] H_{t-n} - L_{t-n} = 0.$$

The chosen height would be given by

$$H_{t-n}^{e} = Y_{t-n} + \frac{\varepsilon}{2C_{t-n}}H_{t-n}^{r} + \frac{1}{C_{t-n}}\sqrt{\left(P_{t-n}^{2} + 2P_{t-n}\varepsilon H_{t-n}^{r} + \left(\varepsilon Y_{t-n}\right)^{2} - 2C_{t-n}L_{t-n}\right)}.$$

Notice that total utility dissipation will cause a builder to increase his height above what he would do if there were "ordinary" height competition. The right most term is a positive function of both income and rival's height and thus would generate a case of even greater height (assuming the right side term is strictly positive).

If builders use a myopic price rule to decide on a height and if price run-ups peak at the height of the business cycle, we would then expect the completed height to come on line during the downturn, after the price has fallen again.

3 Record Breaks and Business Cycles

As mentioned in the Introduction, the popular media (such as Belsie, 2010; Baker (2009), and some economists (Lawrence, 1999; Thorton, 2005) have noted that the world's tallest buildings seem to be completed after the peaks of a cycle. One only has to look at the completion dates for two of the most famous skyscrapers in the world, the Empire State Building (1931) and the Burj Khalifa (2010), to find support for this conclusion.

As the ego model demonstrates, if during boom periods, builders are willing to dissipate their construction profits to engage in height competition, then close to or at the peak of a boom period, builders will be more likely to shoot for record breaks. Given the lag in construction, a record breaking building would come on-line during the period of output declines. Thus, there will be an observed positive correlation between recessions and records.

If building height is a useful predictor of the business cycle, then we should expect to see a pattern between the announcements dates for each building and cycle peaks, and also between the buildings' opening dates and cycle troughs. Table 1 lists the record breaking buildings, the dates that the developers first publicly announced their decisions, and the timing within the business cycle.[6] While it is true that 10 building were announced during an upswing in the cycle, the range of months between the announcement and peak is tremendous, varying from 0 to 45 months.

Table 1:Announcement Dates of Record Breaking Buildings.

	Building	Announced	Nearest U.S. Peak	$(A-P)$ # Months	Nearest U.S.Trough	Direction of Cycle
1	Pulitzer	June 1889	Jul. 1890	-13	Apr. 1888	Up
2	Manhattan Life	Feb. 1892	Jan. 1893	-11	May 1891	Up
3	Park Row	Mar. 1896	Dec. 1895	+3	June 1897	Down
4	Singer	Feb. 1906	May 1907	-15	Aug. 1904	Up
5	Met Life	Jan. 1907	May 1907	-4	Aug. 1904	Up
6	Woolworth	July 1910	Jan. 1910	+6	Jan. 1912	Down
7	40 Wall	Mar. 1929	Aug. 1929	-5	Nov. 1927	Up
8	Chrysler	Oct. 1928	Aug. 1929	-10	Nov. 1927	Up
9	Empire State	Aug. 1929	Aug. 1929	0	Mar. 1933	At Peak
10	Twin Towers	Jan. 1964	Apr. 1960	+45	Feb. 1961	Up
11	Sears Tower	Jul. 1970	Dec. 1969	+7	Nov. 1970	Down
12	Petronas	Aug. 1991	July 1990	+13	Mar. 1991	Up
13	Taipei 101	Oct. 1997	Mar. 2001	-41	Mar. 1991	Up
14	Burj Khalifa	Feb. 2003	Mar. 2001	+23	Nov. 2001	Up

Notes: The table contains record breaking buildings, dates of their announcement, and relationship to the U.S. business cycle. See the Appendix for sources. $(A-P)$ is the number of months before (-) or after (+) announcement and peak. For each building the trough date is the one that either precedes an announcement date that is before a peak, or follows the announcement date that is after a peak.

Looking at the opening dates of the buildings shows a similar story. Table 2 shows the date of opening of each building (i.e., either the official opening or the date that the building received its first tenants), the closest peak and subsequent trough.

[6] In some earlier cases, the first public announcements did not include an intention to break the world record, only that they intended to build a very tall building.

Table 2:Completion Dates of Record Breaking Buildings.

	Building	Open Date	Nearest U.S. Peak	Trough After Peak	$(O-T)$ # Months	Direction of Cycle
1	Pulitzer	Dec. 1890	July 1890	May 1891	-5	Down
2	Manhattan Life	May 1894	Jan. 1893	June 1894	-1	Down
3	Park Row	Apr. 1899	Jun. 1899	Dec. 1900	-20	Up
4	Singer	May 1908	May 1907	June 1908	-1	Down
5	Met Life	Jan. 1910	Jan. 1910	Jan. 1912	-24	At peak
6	Woolworth	Apr. 1913	Jan. 1913	Dec. 1914	-20	Down
7	40 Wall	May 1930	Aug. 1929	Mar. 1933	-34	Down
8	Chrysler	Apr. 1930	Aug. 1929	Mar. 1933	-35	Down
9	Empire State	Apr. 1931	Aug. 1929	Mar. 1933	-22	Down
10	Twin Towers	Dec. 1970	Dec. 1969	Nov. 1970	+1	Up
		Jan. 1972	Nov. 1973	Mar. 1975	-38	Up
11	Sears Tower	Sep. 1973	Nov. 1973	Mar. 1975	-18	Up
12	Petronas	Sep. 1999	Mar. 2001	Nov. 2001	-26	Up
13	Taipei 101	Dec. 2004	Dec. 2007	Jun. 2009	-54	Up
14	Burj Khalifa	Jan. 2010	Dec. 2007	Jun. 2009	+7	Up

Notes: The table contains record breaking buildings, dates of their completion, and relationship to U.S. business cycle. See the Appendix for sources. $(O-T)$ is the number of months before (-) or after (+) opening and the next trough. The trough date follows the peak nearest the opening.

First we can see that only seven out of 14 were completed during the downward phase of the cycle, and furthermore, there is no pattern between when the building is opened for business and when the trough occurs. The range goes from 1 to 54 months. In short, there is no way to predict the business cycle based on either when a record-breaker is announced or when it is completed.

4 Cointegration Analysis

We have developed two versions of a simple skyscraper construction model: with and without ego. The profit maximizing model suggests an integrated relationship between height and income, while the ego models suggest that height and income should systematically move apart overtime. In particular, if ego-based competition is an integral part of the market we would expect height to rise faster than income.

To further explore the issue of height and output, here we investigate annual time series data, using the tallest building completed each year in a particular country and its per capita GDP.[7] If ego-based competition is important it would most likely manifest itself at the upper end of the height distribution. To this end we perform Granger causality and co-integration tests to see how the two series co-move. If we observe co-integration between height and income, this would provide support for the profit-maximizing model; if not, it would provide support for the ego-model. As well, Granger causality can provide further evidence on which model is supported by the data. If output causes height but not the other way around, it would support the profit maximizing model. If height causes output it would support the ego-based model, since that would mean height can be used to forecast recessions, as is strongly implied by the conventional wisdom on record breaking height.

4.1 The United States

Since the U.S. was the pioneer in skyscraper development, it has the longest continuous time series for height for any nation. Figure 1 shows the time series graph from 1885 to 2009; we can see that there is a trend in both series, but steeper for GDP, Y_t, than for height, H_t. Height is from the tallest building completed each year among 14 mainland U.S. cities: Atlanta, Boston, Chicago, Cleveland, Dallas, Detroit, Houston, Los Angeles, Miami, New York, Philadelphia, Pittsburgh San Francisco, and Seattle. Sources are in the appendix.

{Figure 1 about here}

Table 3 presents the results of the time series tests. First, we test for a unit root in the two times series. Next the trace test looks for evidence of co-integration. Below that we show the co-integration relationships and

[7] This analysis fits within a large body of work exploring which macroeconomic variables co-move with output, but this is the first to use height in a vector autoregression. See Stock and Watson (2003) for a review of this literature.

finally we show the Granger causality tests. The AIC selects two lags in the vector autoregression:

$$\begin{bmatrix} \Delta\ln(Y_t) \\ \Delta\ln(H_t) \end{bmatrix} = \begin{bmatrix} \gamma_{10} + \sum_{j=1}^{2}\gamma_{1,j}\Delta\ln Y_{t-j} + \gamma_{1,j+2}\Delta\ln H_{t-j} \\ \gamma_{20} + \sum_{j=1}^{2}\gamma_{2,j}\Delta\ln Y_{t-j} + \gamma_{2,j+2}\Delta\ln H_{t-j} \end{bmatrix} + \begin{bmatrix} \alpha_1(\ln Y_{t-1} + \beta_2 \ln H_{t-1}) \\ \alpha_2(\ln Y_{t-1} + \beta_2 \ln H_{t-1}) \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix} \quad (1)$$

The Johansen trace test suggests one common trend, $r = 1$. We then estimate the cointegrating vector

$$\ln Y_{t-1} - 2.33 \ln H_{t-1}, \quad (2)$$

which indicates that height rises more slowly than GDP, $\ln(H_t) = 0.429 \ln(Y_t)$. When height rises or falls above this average level, there is a statistically significant adjustment to the deviation. $\alpha_2 = 0.126$ implies that it takes $3.97 = 0.5/0.126$ years to adjust halfway to equilibrium.

To confirm the causal role of GDP, we also conduct Granger casualty tests in levels[8] of the VAR portion of 1,

$$\begin{bmatrix} \ln(Y_t) \\ \ln(H_t) \end{bmatrix} = \begin{bmatrix} \gamma_{10} + \sum_{j=1}^{2}\gamma_{1,j}\ln Y_{t-j} + \gamma_{1,j+2}\ln H_{t-j} \\ \gamma_{20} + \sum_{j=1}^{2}\gamma_{2,j}\ln Y_{t-j} + \gamma_{2,j+2}\ln H_{t-j} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix}. \quad (3)$$

We compare the VAR to a restricted model in which set $\gamma_{1,3} = \gamma_{1,4} = 0$. The test statistics for the increase in the log likelihood has an F-distribution with degrees of freedom equal to the number of restrictions. The test cannot reject that height is non-causal for GDP. Conversely, when we restrict $\gamma_{2,1} = \gamma_{2,2} = 0$, the F-statistic of 5.50 rejects the hypothesis that GDP does not Granger cause height. In short, the tests show that both series have a unit root; that there is a co-integrating relationship between the two series, and finally that output Granger causes height but height does not Granger cause output.

[8] The use of levels is required to capture the causal contribution of the error correction terms. Furthermore, the standard F-test on the subregression is inconsistent (see Phillips, 1995).

Table 3:Cointegration of U.S. height and real per capita GDP, 1885-2008.

	Unit Root	
	ADF	
GDP	-0.1802	
Height	-3.1440*	
	Trace Tests	
	$r = 0$	$r = 1$
	17.719*	0.113
(p-val)	(0.02)	(0.74)
	Cointegrating Relationship	
	α	β
GDP	0.005	1
(t-stat)	(0.866)	
Height	0.126*	-2.333*
(t-stat)	(4.276)	(5.858)
	Granger Causality to:	
GDP	From Height	
F-stat	0.3989	
(p-val)	(0.67)	
Height		From GDP
F-stat		5.4985*
(p-val)		(0.01)

Notes: *ADF* is the augmented Dickey-Fuller test for a unit root. The SIC selects 2 lags for the cointegration and Granger causality analysis. We utilize the finite sample corrected trace statistic and approximate p-values from Doornik (1998). *indicates significance at the 95% confidence level.

4.2 Other Countries

We explore the robustness of these results by looking around the globe. We look first at Canada and then at China and Hong Kong (which we consider a distinct entity from China).

4.2.1 Canada

Canada's maximum height and real per capita GDP series are plotted in Figure 2. The output series is nearly perfectly correlated with the U.S. The height series have a correlation of 0.48; it appears to have plateaued slightly later than the U.S. The results of the VAR-related tests for Canada are given in Table 4.

{Figure 2 about here}

Table 4:
Cointegration of Canadian height and real per capita GDP, 1922-2008.

Unit Root		
	ADF	
GDP	-1.0828	
Height	-5.4193*	
Trace Tests		
	$r = 0$	$r = 1$
	21.361*	0.718
(p-val)	(0.01)	(0.40)
Cointegrating Relationship		
	α	β
GDP	0.017	1
(t-stat)	(1.877)	
Height	0.360*	-1.850*
(t-stat)	(4.640)	(7.966)
Granger Causality to:		
GDP	From Height	
F-stat	1.8604	
(p-val)	(0.16)	
Height		From GDP
F-stat		5.7482*
(p-val)		(0.00)

Notes: The sample spans 1922-2008, with 1933, 1940, 1942-46, and 1950 missing. *ADF* is the augmented Dickey-Fuller test for a unit root. The

SIC selects 2 lags for the cointegration and Granger causality analysis. We utilize the finite sample corrected trace statistic and approximate p-values from Doornik (1998). *indicates significance at the 95% confidence level.

Height is from the tallest building completed among the cities Toronto, Montreal, Calgary, Vancouver, Ottawa and Edmonton. Results in Table 4 are quite similar to the U.S.: both time series have a unit root and are co-integrated, and that height does not Granger cause output but output predicts height. The adjustment speed is much faster than the U.S. with a half-life based on α_2 of $1.39 = 0.5/0.360$ years. Height is more responsive to GDP, but it does not rise one-for-one, i.e., $\ln(H_t) = 0.541 \ln(Y_t)$.

4.2.2 China and Hong Kong

The time series plots for GDP and height for China are in Figure 3 and Figure 4. Chinese height still seems to be in an uptrend, but Hong Kong has stabilized since the 1980s.

{Figures 3 and 4 about here}

Table 5 presents the cointegration tests for China and Hong Kong. For China, height comes from the tallest building completed among the following cities: Shanghai, Beijing, Guangzhou, Chongqing, Tianjin,Wuhan, Nanjing and Shenzhen. These cities have highest concentration of skyscrapers in mainland China.

Table 5:
Cointegration of China and Hong Kong Height and real per capita GDP.

Unit Root					
	ADF			*ADF*	
China-GDP	1.6068		HK-GDP	-1.8223	
China-Height	-1.8695		HK-Height	-2.9795*	
Trace Tests					
China	$r = 0$	$r = 1$	HK	$r = 0$	$r = 1$
	20.734*	2.012		39.572*	4.395
(p-val)	(0.01)	(0.16)	(p-val)	(0.00)	(0.69)
Cointegrating Relationship					
	α	β		α	β
China-GDP	0.017	1	HK-GDP	-0.045	1
(t-stat)	(1.191)		(t-stat)	(2.027)	
China-Height	0.888*	-0.721*	HK-Height	0.933*	-0.934*
(t-stat)	(4.188)	(7.904)	(t-stat)	(6.414)	(7.586)
Granger Causality to:					
China-GDP	From Height		HK-GDP	From Height	
F-stat	1.1922			3.4101	
(p-val)	(0.28)			(0.07)	
China-Height		From GDP	HK-Height		From GDP
F-stat		20.1138*			4.2936*
(p-val)		(0.00)			(0.04)

Notes: The China sample runs from 1972-2008, with 1980 missing. Hong Kong's data is from 1950-2008, with 1951-53 missing. *ADF* is the augmented Dickey-Fuller test for a unit root. The SIC selects 1 lag for the cointegration and Granger causality analysis. We utilize the finite sample corrected trace statistic and approximate p-values from Doornik (1998). *indicates significance at the 95% confidence level.

As in the U.S. and Canada, the results from the two Asian markets support the rational model: both height and GDP are non-stationary but cointegrated. The error-correction coefficients are 1.387 for China and 1.072 for Hong Kong, producing half-lives for both countries of under one year. Height also rises more quickly for each 1,000 dollars of GDP in the Asian countries. As growth matures and height plateaus, we should expect both to move towards North American rates.

5 Conclusion

This paper is the first paper to rigorously test how height and output co-move. Because builders can use their buildings for non-rational or non-pecuniary gains, it is widely believed that (a) the most severe forms of height competition occur near the business cycle peaks and (b) that extreme heights are examples of developers "gone wild." The implications of these beliefs are that skyscraper height can be used to predict the business cycle (i.e., height is a leading indicator), and that over time, height and output should deviate because height competition causes builders to build taller than their rivals, rather than what is profit maximizing.

We first look at the announcement and completion dates of record-breaking skyscrapers and find there is very little correlation with the peaks or toughs of the cycles. Second, co-integration and Granger causality tests show that height and output are co-integrated and that height does not Granger cause output, but that output causes height. These results are robust at the international level.

While we don't deny that height competition and ego-based construction are present in the skyscraper market, they do not appear to be a systematic part of the market. The fact that heights rises over the business cycle indicates that height is a response, on average, to rising incomes rather than increased competition or other factors such as shocks to the money supply.

A Appendix: Data Sources

-*Skyscraper Height for Each Country*. For each city in each country, the largest building completed each year was downloaded from Emporis.com and www.skyscraperpage.com. Then for each country, the largest building completed among the chosen cities was selected. In general, for the U.S., 14 cities were selected based on their population, skyscraper concentration and regional representation. Specifically, Atlanta, Chicago, Cleveland, Dallas, Houston, Los Angeles, New York City, Philadelphia and Seattle where chosen because they contain the 20 tallest buildings in the U.S., according to Emporis.com (http://www.emporis.com/statistics/tallest-buildings-usa, accessed January, 2010). Boston, Detroit, Miami, Pittsburgh and San Francisco were added to increase the sample size.

For Canada, Calgary, Montréal, Toronto, and Vancouver were selected because they contain Canada's 20 tallest buildings. (http://www.emporis.com/statistics/tallest-buildings-canada, accessed December 2010). Edmonton and Ottawa were added to increase the sample size.

Hong Kong was selected because it has the highest concentration of skyscrapers for all cities in the world (http://www.emporis.com/statistics/most-skyscrapers, accessed December 2010).

For China, Beijing, Guangzhou, Jiangyin, Nanjing, Shanghai, Shenzhen, Tianjin, Wenzhou, and Wuhan were selected because they contain mainland China's 20 tallest buildings (http://www.emporis.com/statistics/tallest-buildings-china, accessed December 2010). Chongqinq was added to increase the sample size since it has a very high concentration of skyscrapers (http://skyscraperpage.com/cities/?countryID=3, accessed December 2010).

-*Real Per Capita GDP*. U.S: Johnston and Williamson (2010); Canada: Statistics Canada, http://www.statcan.gc.ca/cgi-bin/af-fdr.cgi?l=eng&loc=K172_183-eng.csv; Hong Kong and China: Angus Maddison, http://www.ggdc.net/Maddison;

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Figure 1: Height of tallest completed building versus real per capita GDP in the U.S., 1885-2009

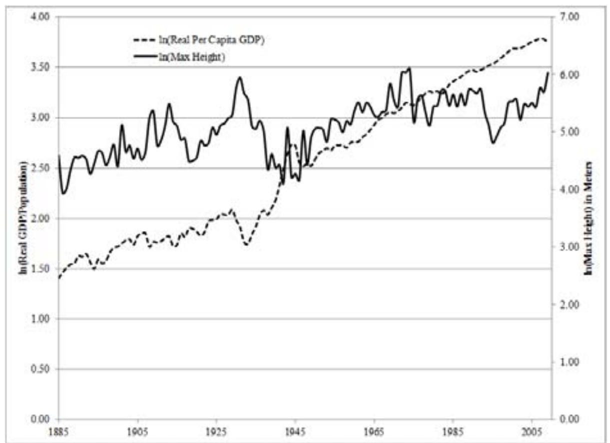

Figure 2: Height of tallest completed building and real per capita GDP in Canada, 1922-2008

Figure 3: Height of tallest completed building vs real per capita GDP in China, 1972-2008.

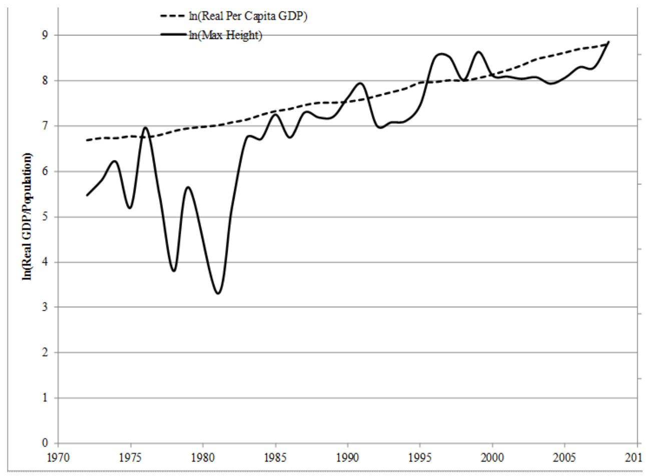

Figure 4: Height of tallest completed building vs. real per capita GDP in Hong Kong, 1950-2008