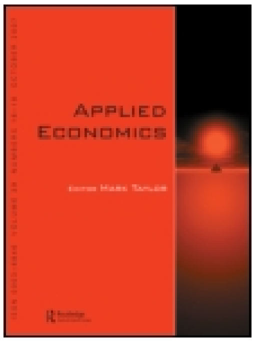

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Skyscraper height and the business cycle: separating myth from reality

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This article is the first to rigorously test how skyscraper height and output co-move. Because builders can use their buildings for nonrational or non-pecuniary gains, it is widely believed that height competition occurs near the business cycle peaks. This would suggest that extreme building height is a leading indicator of GDP, since the tallest buildings are likely to be completed at or near the peak of a cycle. To test these claims, first we look at both the announcement and the 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 while height and output are cointegrated, height does not Granger cause output. These results are robust for the United States, Canada, China and Hong Kong.

Keywords: skyscraper height; business cycle; Granger causality; cointegration

JEL Classification: E3; N1; R33

I. Introduction

Since 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, marketing, emotional and strategic considerations. One World Trade Center (formerly the Freedom Tower) demonstrates the emotional and strategic nature of height. At 1776 feet, this height was chosen to both be the tallest in US and represent the political strength of the American republic.[1]

Despite their importance for cities, nations and the world in general, the determinants of skyscraper height are still poorly understood. Because of their symbolic nature, skyscrapers can serve multiple purposes beyond just providing office and living space. Helsley and Strange (2008), for example, modelled how ego-based motives can generate height competition, which enables the winner to claim the title of ‘tallest building.’ Supertalls are also used as part of regional or national (re)development strategies, such as the Twin Towers in New York, the Burj Khalifa in Dubai and the Petronas Towers in Malaysia. These buildings are used to increase tourism, local investment and job growth by signalling to the world that the region is ‘open for business.’

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

Because of these other objectives, the tallest skyscrapers can be economically 'too tall' in the sense that their constructed heights are higher than what profit maximization would dictate and are thus potentially a misuse of resources.

These deviations from profit maximization also appear to have a predictable pattern within the business cycle. Andrew Lawrence, an economist at Barclay's Bank, has created what he calls a Skyscraper Index, which is not an index but a descriptive timeline showing when the world's tallest buildings were completed and when major financial crises occurred.[2] He states that his timeline 'continues to show an unhealthy correlation between construction of the next world's tallest building and an impending financial crisis: New York 1930, Chicago 1974, Kuala Lumpur 1997 and Dubai 2010. Yet often, the world's tallest buildings are simply the edifice of a broader skyscraper building boom, reflecting a widespread misallocation of capital and an impending economic correction' (Lawrence, 2012, p. 1).

His conclusion gives voice to a popular belief that skyscraper height is a leading indicator of the business cycle, since inefficiencies regarding height decisions are likely to occur at or near the peak of the cycle, when money for such projects is more readily available, and when *Irrational Exuberance* is likely to be present in market transactions (Shiller, 2006). This relationship between building height and the business cycle is widely reported in the media as an accepted fact, and some promote the idea that skyscraper height is, in fact, a 'bubble indicator' (*Economist*, 2006; Baker, 2009; Belsie, 2010; *Economist*, 2010; Mansharamani, 2011; Voigt, 2011; *BBC News*, 2012; Reina, 2012; Barnard, 2013).

If this relationship between height and the business cycle was in fact true, it could have important policy implications. As Shiller (2008) discusses, one of the greatest challenges for economic forecasters is to predict turning points in asset prices. If, in fact, skyscraper height is a leading indicator of an economic downturn, it might prove very useful to governments and the financial community.

Our objective is to better understand the relationship between skyscraper height and the business cycle.[3] We ask: Is extreme height is a leading indicator of the business cycle and, relatedly, have output and height diverged overtime, due to height competition or noneconomic factors? If these noneconomic aspects of skyscrapers are important, then we would likely see skyscraper height rise faster than GDP because developers are competing to out-build each other in order to claim the extra benefits that come with having the title of 'the tallest building.'

To investigate these questions, first we look at record-breaking height. Record-breakers are the most visible skyscrapers and have received the most attention; they are the basis for the Skyscraper Index discussion. If they 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 relationship between record-breakers and recessions.

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 cointegration tests. We perform this analysis for the United States, Canada, China and Hong Kong. We find that in all of these cases, real per capita GDP and height are cointegrated, and there is unidirectional causality from GDP to height. These findings lead us to the conclusions that (1) height is not a useful predictor of the business cycle and (2) while height may temporarily deviate from output, over the long run, height and output move together. These results are robust across countries.

This work fits within two strands of literature. First, this work is placed within the handful of papers on the economics of skyscrapers. Thornton (2005) argues that extreme height is a result of rapid growth in the supply of money. Helsley and Strange (2008) see extreme height emerging from a contest of egos. Clark and Kingston (1930) concluded that extreme height is a rational response to high land values. Barr (2012) finds evidence that in New York City, extreme

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[2] See http://static.nzz.ch/files/6/2/0/Skyscraper+Index+-+Bubble+building+100112+%282%29_1.14300620.pdf for a report that cites the Index. And for a graphic representation of the Index, see http://www.ritholtz.com/blog/wp-content/uploads/2012/02/skyscraper.png

[3] We focus on building height, rather than some other building measures because of the 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 their most discussed aspect by the public at large and by scholars in other disciplines. Future work can explore other dimensions such as their numbers or their bulk.

height is mostly due to economic considerations, but during boom periods, height is also driven by noneconomic consideration such as height competition.

Second, this work extends a large body of work exploring which macroeconomic variables co-move with output (Stock and Watson, 2003). 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 VAR of gross domestic product and measures of real estate investment. He finds that nonresidential 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 work is the first to use height in a VAR; our findings are consistent with these works since we find that skyscraper height does not Granger cause GDP, but is caused by GDP.

The article is divided as follows. In Section II, we present a simple model to provide testable hypotheses. Section III compares the announcement and completion dates of record-breaking skyscrapers within the US business cycle. Section IV discusses the VAR and cointegration analysis, and we conclude in Section V.

II. A Baseline Model

Here, we provide a simple model that links height and macroeconomic output, stripping out the local factors emphasized in Barr (2010). The aim of the model is to provide a predicted relationship between height and output if builders were profit maximizers and not concerned with their symbolic height.

A developer who intends to construct a skyscraper maximizes the following profit function:

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

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 (announced) height and $(C_{t-n}/2)H_{t-n}^2$ is the construction cost associated with building of height H_{t-n}, assumed to be increasing at an increasing rate (Barr, 2010). L_{t-n} is the fixed cost of land (assume all plots are normalized to one unit). Here, we assume that builders use the current price for the expected price, $E_{t-n}P_t = P_{t-n}$ (Wheaton, 1999; McDonald, 2002).

Profit maximization yields a 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 is the value-added from the project. Since our interest is to understand the relationship between building height and the business cycle, our measure of income is GDP. While this represents a certain level of abstraction, we feel that GDP is a useful indicator for income, as it is a good measure of the demand for real estate. Our Granger causality tests, reported in the following, also support the use of GDP as a measure of income.[4]

However, since there are lags in construction, we assume that builders will 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:

$$H_t = H_{t-n}^* + \beta_{n+1}\Delta Y_{t-n+1} + \cdots + \beta_1\Delta Y_{t-1}$$

where $0 < \beta_j < 1$. Since builders have to pay some adjustment costs, we assume they cannot fully adjust the heights as incomes change. Based on Barr (2010), who finds a 2-year average completion time in New York City, we set $n = 2$, to give a height equation of:

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

Equation 1 shows that if builders maximize profits from construction, then heights will be a positive, linear function of net income, and thus, the two will have an ‘integrated’ relationship. The model also implies that if skyscraper height was an economic decision, rather than a psychological one, at the aggregate level, we should expect to see GDP and height co-move with an integrated relationship as

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[4] For the US, the results discussed later are the same if we replace GDP with the real estate construction portion of GDP. These kind of data, however, are not available for the other countries.

well, since GDP is the value-added of all goods and services produced in the economy. Furthermore, if height and output are linked, we would expect tall buildings to come online after peaks because of the long lags in construction. The profit maximizing model suggests that height should ‘follow’ income, rather than the other way around.

Systematic errors

The idea that the tallest buildings can be used to forecast downturns implies that builders are overly optimistic about the state of the economy, or that they believe the future will be so rosy that they can dissipate some profits for ego purposes without having to abandon the project. If over-optimism is an ongoing part of the skyscraper construction, then builders must make systematic forecasting errors that could be used to predict the timing of a downturn. In general, height is determined by the expectation of income, at the time the height decision is made.

$$H_{t-n} = E_{t-n}[Y_t]$$

But if builders are overly optimistic, particularly when the economy is rapidly growing, it means that

$$\left(E_{t-n}Y_t - E^r_{t-n}Y_t\right) > 0$$

where E^r_{t-n} is the expectations operator that yields no systematic errors in forecasting, so that $Y_t = E^r_{t-n}Y_t + \varepsilon_t$, and ε_t is a random error term, with mean zero. That is, on average, builders accurately predict the income from the project. Now, let’s say, for simplicity, that the over-optimism of builders can be expressed as $E_{t-n}Y_t = Y_t + O$, where $O > 0$, so that actual income is given by $Y_t = E^r_{t-n}Y_t - O + \varepsilon_t$.

Chosen (announced) height is thus

$$H_{t-n} = Y_t + O$$

Let’s further assume that the overly optimistic builder carries on and does not change his project size based on new information because he has a biased belief that his project is special, so that $H_t = H_{t-n}$.[5] In this case, we are likely to see two outcomes. One is that GDP is Granger caused by height, $Y_t = H_{t-n} + O$, and second, there are long-run deviations of height and income, since $\left(E_{t-n}Y_t - E^r_{t-n}Y_t\right) > 0$. This would also imply that height and income are not cointegrated and move apart in the long run, due to the need to compete with each other and because ego drives overly rosy views of the economy.

III. Record Breaks and Business Cycles

As discussed earlier, the popular media and some economists (Thornton, 2005; Lawrence, 2012) 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. Thus, if record-breaking height is a useful predictor of the business cycle, then we should expect to see a pattern between the announcement dates for each building and cycle peaks and between the buildings’ opening dates and cycle troughs as well. Here, we investigate if record-breaking height presents systematic deviations from the profit-maximizing model.

Table 1 lists all of the record-breaking buildings completed since 1890, the dates that the developers first publicly announced their decisions, and the timing within the business cycle.[6] Without loss of generality, we use the US business cycle because of its importance for the world economy, and because, until relatively recently, all the record-breakers were in the US.[7]

While it is true that 10 buildings 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.

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[5] Shiller (2008) discusses some systematic biases in real estate investments, including what he calls the ‘uniqueness bias,’ which is a tendency for investors to falsely believe their particular investment is uniquely special and more valuable than other investments (p. 5).

[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. Also note we omitted some early buildings that had nonoccupied clock towers.

[7] Note that the Asian financial crises began in June of 1997. The Taipei 101 was announced in October 1997, about four months after that. The Petronas Towers had been announced several years before then and was officially opened in mid-1999, although it began to be occupied as early as January 1997 (http://www.petronastwintowers.com.my/).

Table 1. Announcement dates of record-breaking buildings

	Building	Announced	Nearest US peak	$(A-P)$ # Months	Nearest US trough	Direction of cycle
1	Pulitzer	June 1889	July 1890	−13	April 1888	Up
2	Manhattan Life	February 1892	January 1893	−11	May 1891	Up
3	Park Row	March 1896	December 1895	+3	June 1897	Down
4	Singer	February 1906	May 1907	−15	August 1904	Up
5	Met Life	January 1907	May 1907	−4	August 1904	Up
6	Woolworth	July 1910	January 1910	+6	January 1912	Down
7	40 Wall	March 1929	August 1929	−5	November 1927	Up
8	Chrysler	October 1928	August 1929	−10	November 1927	Up
9	Empire State	August 1929	August 1929	0	March 1933	At peak
10	Twin Towers	January 1964	April 1960	+45	February 1961	Up
11	Sears Tower	July 1970	December 1969	+7	November 1970	Down
12	Petronas	August 1991	July 1990	+13	March 1991	Up
13	Taipei 101	October 1997	March 2001	−41	March 1991	Up
14	Burj Khalifa	February 2003	March 2001	+23	November 2001	Up

Notes: The table contains record-breaking buildings, dates of their announcement and relationship to the US business cycle. See Appendix 1 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.

Table 2. Completion dates of record-breaking buildings

	Building	Open date	Nearest US peak	Trough after peak	$(O-T)$ # months	Direction of cycle
1	Pulitzer	December 1890	July 1890	May 1891	−5	Down
2	Manhattan Life	May 1894	January 1893	June 1894	−1	Down
3	Park row	April 1899	June 1899	December 1900	−20	Up
4	Singer	May 1908	May 1907	June 1908	−1	Down
5	Met Life	January 1910	January 1910	January 1912	−24	At peak
6	Woolworth	April 1913	January 1913	December 1914	−20	Down
7	40 Wall	May 1930	August 1929	March 1933	−34	Down
8	Chrysler	April 1930	August 1929	March 1933	−35	Down
9	Empire state	April 1931	August 1929	March 1933	−22	Down
10	Twin towers	December 1970	December 1969	November 1970	+1	Up
		January 1972	November 1973	March 1975	−38	Up
11	Sears tower	September 1973	November 1973	March 1975	−18	Up
12	Petronas	September 1999	March 2001	November 2001	−26	Up
13	Taipei 101	December 2004	December 2007	June 2009	−54	Up
14	Burj Khalifa	January 2010	December 2007	June 2009	+7	Up

Notes: The table contains record-breaking buildings, dates of their completion and relationship to US business cycle. See Appendix 1 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.

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.

First, we can see that only 7 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 is from 1 to 54 months. In short, contrary to popular belief, there is no way to predict the business cycle, or financial panic, based on either when a record-breaker is announced or when it is completed.

IV. Cointegration Analysis

As discussed earlier, if developers are primarily profit maximizers, we would expect to see height and output move in a predictable fashion, where height is positively related to GDP. If, on the other hand, developers are strategically motivated to out-build each other, then we might expect the two series to move apart. To further explore the issue of height and output, we investigate annual time series data, using the tallest building completed each year in a particular country and its real per capita GDP. If psychological needs are important, they would most likely manifest themselves at the upper end of the height distribution. To this end, we perform Granger causality and cointegration tests to see how the two series co-move. If height can predict GDP, we would expect to see it Granger-cause output. In addition, if noneconomic motives are important, we would expect not to find a cointegrating relationship between the two series. Height competition would presumably cause height to deviate from GDP as builders try to spend some of their income on securing themselves a favourable position in the height hierarchy, rather than focusing on economic fundamentals *per se*.

Appendix 1 contains information about the sources of the data, and Appendix 2 contains descriptive statistics. To the best of our knowledge, data on the skyscrapers are exhaustive and complete. Based on prior research, height is strongly correlated with other skyscraper measures, such as their annual completion frequencies and their average heights (Barr, 2010, 2013). Note that, for this section, we only have data on completion dates and not announcement or start dates. While it is possible that completion lags may have changed over the twentieth century, the results support that 2 years represents the best fit of the data. All the height and the GDP series are integrated of order one. In addition, it's not clear, *a priori*, that lags have become longer over time as buildings become taller. On one hand, taller buildings do take longer to complete, but on the other hand, technological improvements may have also shortened the length of time needed to finish the project. We leave for future work a study of the evolution of completion lags; however, we do not feel that this impacts our results.

The United States

Since the US 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 US cities: Atlanta, Boston, Chicago, Cleveland, Dallas, Detroit, Houston, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco and Seattle.

Table 3 presents the results of the time series tests. We use the Johansen trace test to look for evidence of cointegration. The AIC selects two lags in the VAR:

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

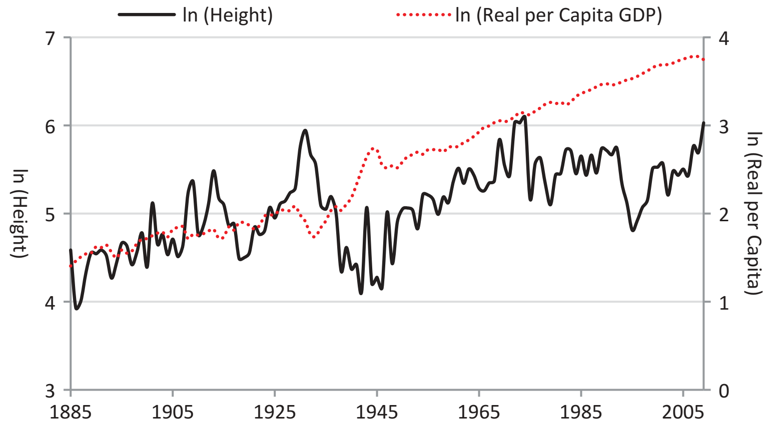

Fig. 1. Height of tallest completed building and real per capita GDP in the US, 1885–2009

Table 3. Cointegration and Granger causality tests of US height and real per capita GDP, 1885–2009

Trace tests		
	$r = 0$	$r = 1$
	17.719*	0.113
(*p*-Value)	(0.02)	(0.74)
Cointegrating relationship		
	α	β
GDP	0.005	1
(*t*-Statistic)	(0.866)	
Height	0.126*	−2.333*
(*t*-Statistic)	(4.276)	(5.858)
Granger causality to:		
GDP	From height	
F-Statistic	0.3989	
(*p*-Value)	(0.67)	
Height		From GDP
F-Statistic		5.4985*
(*p*-Value)		(0.01)

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

The Johansen trace test suggests one common trend, $r = 1$.[8] The estimated cointegrating vector is

$$\ln \boldsymbol{Y}_{t-1} - 2.33 \ln \boldsymbol{H}_{t-1} \tag{3}$$

which indicates that height rises more slowly than GDP and $\ln(\boldsymbol{H}_t) = 0.429 \ln(\boldsymbol{Y}_t)$. 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 conducted Granger casualty tests in levels of the VAR portion of Equation 2[9]:

$$\begin{bmatrix} \ln(Y_t) \\ \ln(H_t) \end{bmatrix} = \begin{bmatrix} \gamma_{10} + \sum_{j=1}^{2} \left(\gamma_{1,j} \ln Y_{t-j} + \gamma_{1,j+2} \ln H_{t-j} \right) \\ \gamma_{20} + \sum_{j=1}^{2} \left(\gamma_{2,j} \ln Y_{t-j} + \gamma_{2,j+2} \ln H_{t-j} \right) \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix} \tag{4}$$

We compare the VAR to a restricted model in which we set $\gamma_{1,3} = \gamma_{1,4} = 0$. The likelihood ratio test has an F-distribution with degrees of freedom equal to the number of restrictions. The test cannot reject that height is noncausal 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 common trend, indicating a cointegrating relationship between the two series; finally, output Granger causes height but height does not Granger cause output. These findings provide evidence that skyscraper height is a rational response to changes in GDP.

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).

Canada. Canada's maximum height and real per capita GDP series are plotted in Fig. 2. Height is from the tallest building completed among the cities of Calgary, Edmonton, Montreal, Ottawa, Toronto and Vancouver. The output series is nearly perfectly correlated with the US. The Canadian height series has correlation of 0.48 with the US height series. Height in Canada appears to have plateaued slightly later than in the US. The results of the VAR-related tests for Canada are given in Table 4.

The results in Table 4 are quite similar to the US: the two series are cointegrated, in addition, height does

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[8] Gonzalo and Lee (1998) note that the Johansen test can have poor properties in cases where there is not an exact unit root. They recommend using the Engle–Granger test as a robustness check, and we have done that for all the GDP-height combinations. Each country rejects the null of no cointegration at the 1% level using the McKinnon (1991) critical values.

[9] 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). As a further robustness check, we performed the Toda–Yamamoto test (Toda and Yamamoto, 1995) for causality which is robust to nonstationarity. This test rejected the null of no Granger causality from GDP to height at the 7% level.

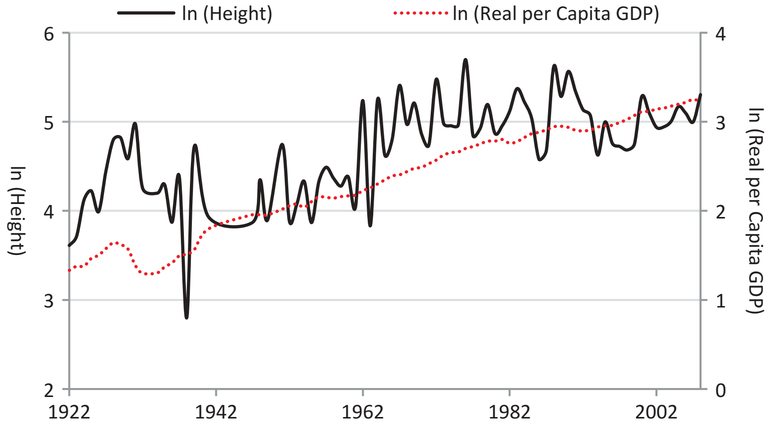

Fig. 2. Height of tallest completed building and real per capita GDP in Canada, 1922–2008

Table 4. Cointegration and Granger causality tests of Canadian height and real per capita GDP, 1922–2008

Trace tests		
	$r = 0$	$r = 1$
	21.361*	0.718
(p-Value)	(0.01)	(0.40)
Cointegrating relationship		
	α	β
GDP	0.017	1
(t-Statistic)	(1.877)	
Height	0.360*	−1.850*
(t-Statistic)	(4.640)	(7.966)
Granger causality to:		
GDP	From height	
F-Statistic	1.8604	
(p-Value)	(0.16)	
Height		From GDP
F-Statistic		5.7482*
(p-Value)		(0.00)

Notes: The sample spans 1922–2008, with 1933, 1940, 1942–46 and 1950 are missing. Tests are based on levels data. The SIC selects two lags for the cointegration and Granger causality analysis. We utilise the finite sample corrected trace statistic and approximate p-values from Doornik (1998). *indicates significance at the 95% confidence level.

not Granger-cause output, but output predicts height. The adjustment speed is much faster than that of the US 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., $\ln(H_t) = 0.541\ln(Y_t)$.

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

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

As with the US and Canada, the results from the two Asian markets support the rational model: height and GDP are cointegrated. The error-correction coefficients are 1.387 for China and 1.072 for Hong Kong, respectively, producing half-lives for both countries of under 1 year. Height also rises more quickly for each 1000 dollars of GDP in the Asian countries. As growth stabilizes and building height plateaus, we should expect both to move towards North American rates. The Chinese half-life is probably so small due to its rapid economic development and urbanization over the last few decades. Similar to North America, height does not Granger-cause output in Asia.

In summary, the cointegration and Granger causality tests for all the countries support that height is driven by GDP and not the other way around; this supports the profit-maximizing model and rejects the implications of the Skyscraper Index.

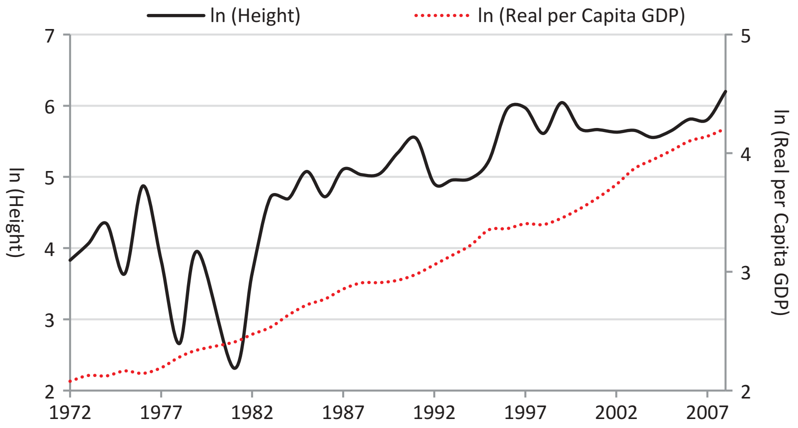

Fig. 3. Height of tallest completed building and real per capita GDP in China, 1972–2008

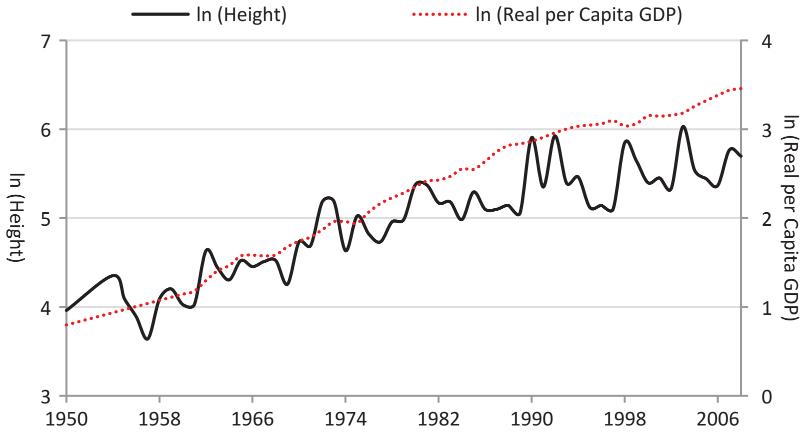

Fig. 4. Height of tallest completed building and real per capita GDP in Hong Kong, 1950–2008

V. Conclusion

The drivers of skyscraper height are still not well understood. There is a wide perception that because skyscrapers can be used for noneconomic purposes, the tallest skyscrapers are economically 'too tall,' and these noneconomic motives manifest themselves within predictable locations in the business cycle. This article is the first one to rigorously test how skyscraper height and output co-move.

The Skyscraper Index, a descriptive timeline (not a real index), created by economist Andrew Lawrence (2012), and widely discussed in the popular media, purports to show the relationship between the business cycle and excessive height. Since the Index implies that skyscraper height can be used to predict the business cycle, height should be a leading indicator. The Index also implies that over time, height and output should deviate because the positional nature of height causes builders to build taller than their rivals, instead of what is profit maximizing (Frank, 2005). Given that the economics profession still lacks useful predictors for turning points in asset prices, we investigate if skyscraper height can, in fact, be used as a 'bubble indicator.'

To this end, 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, cointegration and Granger causality tests show that in both North America and Asia, height and output are cointegrated and output unidirectionally Granger causes height. These results are consistent with our model of profit-maximizing developers. The results also reject the correlations put forth by the Skyscraper Index; skyscraper height is not a useful measure for turning points.

While we don't deny that psychological and ego-based motives are present in the skyscraper market, they do not appear to be a systematic part of it. The

Table 5. Cointegration and Granger causality tests of China and Hong Kong height and real per capita GDP

Trace tests					
China	$r = 0$	$r = 1$	HK	$r = 0$	$r = 1$
	20.734*	2.012		39.572*	4.395
(p-Value)	(0.01)	(0.16)	(p-Value)	(0.00)	(0.69)
Cointegrating relationship					
	α	β		α	β
China GDP	0.017	1	HK GDP	−0.045	1
(t-Statistic)	(1.191)		(t-Statistic)	(2.027)	
China height	0.888*	−0.721*	HK height	0.933*	−0.934*
(t-Statistic)	(4.188)	(7.904)	(t-Statistic)	(6.414)	(7.586)
Granger causality to:					
China-GDP	From height		HK GDP	From height	
F-Statistic	1.1922			3.4101	
(p-Value)	(0.28)			(0.07)	
China height		From GDP	HK height		From GDP
F-Statistic		20.1138*			4.2936*
(p-Value)		(0.00)			(0.04)

Notes: The China sample runs from 1972 to 2008, with 1980 missing. Hong Kong's data are from 1950 to 2008, with 1951–1953 missing. Tests are based on levels data. The SIC selects one lag for the cointegration and Granger causality analysis. We utilise the finite sample corrected trace statistic and approximate p-values from Doornik (1998). *indicates significance at the 95% confidence level.

fact that heights rise over the business cycle indicates that height is a rational response, on average, to rising incomes.

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References

Baker, T. (2009) When skyscrapers signal a downturn. *Guardian.co.uk*, October 13. Available at http://www.guardian.co.uk/artanddesign/2009/oct/13/sky-scrapers-signal-downturn (accessed 2 October 2014).

Barnard, L. (2013) Saudi shoots for the stars as 1 Mkm-tall Kingdom tower set to rise. *The National*, March 13. Available at http://www.thenational.ae/thenational-conversation/industry-insights/property/saudi-shoots-for-the-stars-as-1km-tall-kingdom-tower-set-to-rise#full (accessed 2 October 2014).

Barr, J. (2010) Skyscrapers and the Skyline: Manhattan, 1895–2004, *Real Estate Economics*, **38**, 567–97. doi:10.1111/j.1540-6229.2010.00277.x

Barr, J. (2012) Skyscraper height, *The Journal of Real Estate Finance and Economics*, **45**, 723–53. doi:10.1007/s11146-010-9274-z

Barr, J. (2013) Skyscrapers and Skylines: New York and Chicago, 1885–2007, *Journal of Regional Science*, **53**, 369–91.

Belsie, L. (2010) World's tallest building: is the Burj Khalifa a herald of economic woe? *The Christian Science Monitor*, January 4. Available at www.csmonitor.com (accessed 2 October 2014).

Clark, W. C. and Kingston, J. L. (1930) *The Skyscraper: A Study in the Economic Height of Modern Office Buildings*, American Institute of Steel Construction, New York.

Doornik, J. A. (1998) Approximations to the asymptotic distributions of cointegration tests, *Journal of Economic Surveys*, **12**, 573–93. doi:10.1111/1467-6419.00068

Frank, R. H. (2005) Positional externalities cause large and preventable welfare losses, *American Economic Review, Papers and Proceedings*, **95**, 137–41. doi:10.1257/000282805774670392

Gonzalo, J. and Lee, T.-H. (1998) Pitfalls in testing for long run relationships, *Journal of Econometrics*, **86**, 129–54. doi:10.1016/S0304-4076(97)00111-5

Green, R. K. (1997) Follow the leader: how changes in residential and non-residential investment predicts changes in GDP, *Real Estate Economics*, **25**, 253–70. doi:10.1111/1540-6229.00714

Helsley, R. W. and Strange, W. C. (2008) A game-theoretic analysis of skyscrapers, *Journal of Urban Economics*, **64**, 49–64. doi:10.1016/j.jue.2007.08.004

Hubris in brick and mortar. (2010) *Economist*, June 28. Available at http://www.economist.com/blogs/free-exchange/2010/06/skyscrapers (accessed 2 October 2014).

Johnston, L. and Williamson, S. H. (2010) What was the US GDP then? MeasuringWorth. Available at http://www.measuringworth.org/usgdp/ (accessed 2 October 2014).

Lawrence, A. (2012) Skyscraper Index. Barclays Capital Equity Research Report, January 12.

Mansharamani, V. (2011) Skyscrapers Are a Great Bubble Indicator. *Forbes*. Available at http://www.forbes.com/2011/03/10/skyscrapers-burj-dubai-leadership-leaders-bubbles.html (accessed 2 October 2014).

McCue, T. E. and Kling, J. L. (1994) Real estate returns and the macroeconomy: some empirical evidence from real estate investment trust data, 1972–1991, *The Journal of Real Estate Research*, **9**, 277–87.

McDonald, J. F. (2002) A survey of econometric models of office markets, *Journal of Real Estate Literature*, **10**, 223–42.

McKinnon, R. (1991) Critical values for cointegration tests, in *Long-Run Economic Relationships*, Engle, R. F. and Granger, C. W. J. (Eds), Oxford University Press, London.

Phillips, P. C. B. (1995) Fully modified least squares and vector autoregression, *Econometrica*, **63**, 1023–78. doi:10.2307/2171721

Reina, P. (2012) Study claims correlation between super-tower construction and economic busts. *Engineering News-Record*, February 6.

Shiller, R. (2006) *Irrational Exuberance*, 2nd edn, Princeton University Press, Princeton, NJ.

Shiller, R. (2008) Historic turning points in real estate, *Eastern Economic Journal*, **34**, 1–13. doi:10.1057/palgrave.eej.9050001

Skyscrapers 'linked with impending financial crashes'. (2012) *BBC News*, 10 January. Available at http://www.bbc.com/news/business-16494013 (accessed 14 October 2014).

Stock, J. H. and Watson, M. W. (2003) Forecasting output and inflation: the role of asset prices, *Journal of Economic Literature*, **41**, 788–829. doi:10.1257/jel.41.3.788

The skyscraper boom: better than flying. (2006) *Economist*, June 1.

Thornton, M. (2005) Skyscrapers and business cycles, *The Quarterly Journal of Austrian Economics*, **8**, 51–74. doi:10.1007/s12113-005-1016-3

Toda, H. Y. and Yamamoto, T. (1995) Statistical inference in vector autoregressions with possibly integrated processes, *Journal of Econo-metrics*, **66**, 225–50. doi:10.1016/0304-4076(94)01616-8

Voigt, K. (2011) China skyscraper boom portend a property crash?, January 5. Available at http://business.blogs.cnn.com (accessed 2 October 2014).

Wheaton, W. C. (1999) Real estate 'cycles': some fundamentals, *Real Estate Economics*, **27**, 209–30. doi:10.1111/1540-6229.00772

Appendix 1: 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 US, 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 were chosen because they contain the 20 tallest buildings in the US, 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 among 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. US: 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.

Business cycle dates. NBER: http://www.nber.org/cycles.html.

Sources for announcements and completions

(1) Pulitzer. Announcement (A): "Not as High as 'The Times' Building." (1889). *New York Times*, June 1, p. 8. Completion (C): "An Unexpected Boom: The Pulitzer Celebration Comes Near Blowing up the City Hall." (1890). *New York Times*, December 11, p. 3.

(2) Manhattan Life (A): 'In and About the City' (1892). *New York Times*, February 26, p. 9. (C): 'The Manhattan Life Building, Ready 1 May 1894.' (Advertisement). (1894). *New York Times*, March 15, p. 12

(3) Park Row. (A): 'In the Real Estate Field. A New Tall Building Planned for Park Row.' (1896). *New York Times*, 5 March 1896. (C): 'Park Row Building Ready for Occupancy' (Advertisement). (1899). *New York Times*, April 1, p. 10.

(4) Singer. (A): 'Tallest Skyscraper to Stand in Broadway.' (1906). *New York Times*. February 22, p. 1. (C): 'The Highest Office Building in the World: It Will be Ready for Occupancy 1 May 1908.' (1907). *New York Times*, April 14, p. R6.

(5) Met Life. (A): 'The 50-story Tower: Its Plan Announced.' (1907). *New York Times*, January 4, p. 2. (C): 'Metropolitan Life has Jubilee Dinner.' (1910). *New York Times*, January 23, p. 12.

(6) Woolworth. (A): 'New Woolworth Building on Broadway Will Eclipse Singer Tower in Height.' (1910). *New York Times*, November 13, p. RE1. (C): '55-Story Building Opens on a Flash.' (1913). *New York Times*, April 25, p. 20.

(7) 40 Wall. (A): 'Building in Wall St. to Rise 64 Stories.' (1929). *New York Times*, 7 April 2024. (C): 'Bank of Manhattan Built in Record Time.' (1930). *New York Times*, May 6, p. 53.

(8) Chrysler. (A): 'Chrysler Plans 68-Story Building in Midtown; $14,000,000 Edifice to Top Woolworth Tower.' (1928). *New York Times*, 17 October 1928. (C): 'Chrysler Building Opens.' (1930). *New York Times*, April 16, p. 57.

(9) Empire State. (A): 'Smith to Help Building Highest Skyscraper.' (1929). *New York Times*, August 30, p. 1. (C): 'Huge Empire State Opens this Week.'(1931). *New York Times*, April 26, p. RE1.

(10) Twin Towers. (A): 'Biggest Buildings in World to Rise at Trade Center.' (1964). *New York* Times, January 19, p. 1. (C): http://wtc.nist.gov/NCSTAR1/PDF/NCSTAR 1–1.pdf, p. xxxvi.

(11) Sears Tower. (A): 'New Sears Building in Chicago Planned as the World's Tallest.' (1970). *New York Times*, 28 July 2018. (C): 'Sears Tower Getting Occupants.' (1973). *Washington Post*, September 15, p. E24.

(12) Petronas. (A): Abada, G. (2004), "Petronas Office Towers." http://www.akdn.org/akaa_ award9_awards_detail7.asp. (C): 'Petronas Towers-New Spirit of Malaysia.' (1999). *The Independent*, September 24.

(13) Taipei 101. (A): Wikipedia, http://en.wikipedia.org/wiki/Taipei_101#Construction_Chronology. (C): 'Now Opening: New Projects Around the World: Taipei 101, Taiwan.' (2004). *Architectural Record*, December, 192(12), p. 34.

(14) Burj Khalifa. (A): 'Dubai to Build World's Tallest Tower.' (2003). Press Release, February 25, http://ameinfo.com/blog/finance-and-economy/2003/dubai-to-build-worlds-tallest-tower/. (C): 'Dubai Opens a Tower to Beat All.' (2010). *New York Times*, January 4.

Appendix 2: Summary of data descriptive statistics

Variable	Mean	SD	Min.	Max.	# Obs.
Canada					
Year	1967.2	25.4	1922	2008	79
Height (meters)	124.3	59.9	16	298	79
Per capita GDP*	12.68	6.67	3671	25.80	79
China					
Year	1977.4	23.4	1929	2008	51
Height (meters)	153.2	121.1	10	492	51
Per capita GDP*	2.00	1.70	525	6.73	51
Honk Kong					
Year	1980.4	16.4	1950	2008	56
Height (meters)	165.8	90.2	38	415	56
Per capita GDP*	12.74	8.7	2218	31.70	56
United States					
Year	1947.0	36.23	1885	2009	125
Height (meters)	182.0	86.0	51	442.3	125
Per capita GDP*	16.54	12.0	4.07	43.95	125

Notes: *GDP figures in real US dollars ($1000). For sources, see Appendix 1.