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Skyscrapers and the Skyline: Manhattan, 1895–2004

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This article investigates the market for skyscrapers in Manhattan from 1895 to 2004. Clark and Kingston (1930) have argued that extreme height is a result of profit maximization, while Helsley and Strange (2008) posit that skyscraper height can be caused, in part, by strategic interaction among builders. I provide a model for the market for building height and the number of completions, which are functions of the market fundamentals and the desire of builders to stand out in the skyline. I test this model using time series data. I find that skyscraper completions and average heights over the 20th century are consistent with profit maximization; the desire to add extra height to stand out does not appear to be a systematic determinant of building height.

Skyscrapers have captured the public imagination since the first one was completed in Chicago in the mid-1880s. Soon thereafter Manhattan skyscrapers became the key symbol of New York's economic might. Although the existence and development of skyscrapers and the skyline are inherently economic phenomena, surprisingly little work has been done to investigate the factors that have determined this skyline.

In Manhattan, since 1894, there have been five major skyscraper building cycles, where I define a "skyscraper" as a building that is 100 m or taller.[1] The average duration of the first four cycles has been about 26 years, with the average heights of completed skyscrapers varying accordingly. Table 1 details the periods of these cycles. The fact that major skyscraper cycles last, on average, a quarter

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[1] Clearly the definition of what constitutes a "skyscraper" has evolved over the last century and a quarter, but for simplicity, I have chosen a fixed number. 100-m buildings have been regularly built since 1895 (Figure 1); this set of buildings represents the tallest of the tall. The measure of building height used here is structural height, which does not include any additional antennae or decorative elements. The average number of floors for a 100-m building is 29.6. One can predict the number of floors from the height via the ordinary least squares (OLS)-derived equation: $\widehat{floors} = \underset{(9.46)}{7.36} + \underset{(41.14)}{0.217}\,\text{m}$. $R^2 = 0.74$, number of obs. is 595; t statistics below estimates. *Sources*: See the Appendix.

Table 1 ■ Major skyscraper building cycles in Manhattan.

Cycle	Period[a]	No. of Years	Year of Peak	No. of Completions in Peak Year
1	1894–1919	26	1914	2
2	1920–1945	26	1931	28
3	1946–1977	32	1974	19
4	1978–1997	20	1986	30
5	1998–	–	–	–
Average cycle length		26		

[a]Trough to trough.
Source: Author's calculations based on data acquired from emporis.com and skyscraperpage.com. The time-series graph of completions and average heights is given later.

of a century indicates that their construction (and heights) is determined by major economic, demographic and political forces, rather than simply the ebb and flow of production and consumption.[2]

Theories of Skyscraper Height

In regard to height, developers face a choice about how tall to build because they face a trade-off between bulk or height for a given plot size. Adding height generates additional rental income, status opportunities and dramatic views, but it comes with increasing marginal costs. In New York City, the construction of tall buildings reflects the demand for dense office and housing space in a market where land costs are high, plot sizes are small and agglomeration economies are great. As a result, building height is relatively more important in the contribution to total rentable space than is the horizontal area.

Although there has not been much academic work on the economics of skyscrapers, the debate about the role of economics versus "ego" has been explored. The first and most-cited work on the economic factors that drive height is that of Clark and Kingston (1930) (herein CK). To address the popular criticism of the day that skyscrapers in the late 1920s were "too tall," that is, built as monuments not as money makers, CK presented a cost–benefit analysis of a hypothetical skyscraper on a large plot of land across from Grand Central Station, in Manhattan's midtown business district. They determined that, given the costs of land and construction and current rent levels, the profit-maximizing

[2] From 1893 to 2004 there have been 24 business cycles in the United States, as measured by the National Bureau of Economic Research (http://www.nber.org/cycles.html/).

height would be 63 stories.[3] They conclude that the very tall buildings being constructed at the time were consistent with profit maximization.

An alternative theory about skyscraper height has recently been put forth by Helsley and Strange (2008) (herein HS). They present a game-theoretic model of two developers competing against each other to build a city's tallest building.[4] In the sequential game version of the model, if one developer has a more favorable location, he or she will use this advantage and strategically add extra height (beyond the profit-maximizing height) to preempt the other developer from winning the race. In the simultaneous game version, the equilibrium is a mixed strategy, where each assigns a positive probability to building a "too tall" skyscraper.

Both theories, however, investigate skyscraper height for only one or two builders. CK conclude from one hypothetical data point that the market for skyscrapers, as a whole, is profit maximizing. HS conclude that, if two builders are competing for a region's tallest building, then the outcome, from a profit-maximization point of view, will be inefficient. Although a strategic-interaction model may be appropriate to understand the right tail of the height distribution, the question investigated here is: At the *market level*, is the quest for status or ego promotion a systematic component of skyscraper construction, or is building height, on average, consistent with profit maximization?

In this article, I provide another interpretation of the effects of ego. Rather, ego is viewed as a desire to stand out or be seen amid the crowded skyline; I aim to understand how builders may or may not use their buildings as a way to advertise and be noticed in general. In this sense, skyscraper height can be viewed as a result of builders' desire to keep up with the Joneses or the other buildings around them (Dupor and Liu 2003). Thus, skyscraper height may be a way for builders to obtain a degree of societal status.[5]

[3] The conclusion that the profit-maximizing height was 63 stories was based on a current-looking model of prices; that is to say, given that land prices were peaking in 1929, the economic height was based in part on myopic expectations. CK assumed that land values were $200 per square foot, the value of land in 1929. An assumption of $400 per square foot would have put the economic height at 75 stories (New York Times 1929).

[4] HS view builders' egos as one of the main drivers of "too tall" construction. For brevity, I will use the term "ego" as shorthand for all of the possible reasons that a builder (whether an individual or corporation) may desire extra height above the profit-maximizing level.

[5] Note that it is possible that taller buildings receive rent premiums. Although this may be true to some degree (although, to my knowledge, there has been no work that studies this), it seems reasonable to assume that, for extremely tall buildings, marginal costs are rising faster than marginal revenues.

The different types of architectural crowns and cupolas and the varying shapes of the tops of skyscrapers strongly suggest that builders want viewers to look up and observe the heights of their buildings; these architectural elements exist for many buildings and not just the record-breaking ones. In the model provided below, builders add extra height as a function of the average height of the skyline. That is to say, I investigate a form of strategic interaction at the market level, where builders use the mean height of the skyline as a benchmark for standing out.

Summary of Findings

This article studies the market for height by focusing on Manhattan from 1895 to 2004. The model is tested using time-series data. The general conclusion of this article is that, on average, the data support the profit-maximization hypothesis, rather than the ego hypothesis. That is to say, although some individual builders may add extra height because of the desire to stand out, these occurrences do not appear in the aggregate at the market level.

The data show the following.

1. Since the early 20th century, there has been no time trend in the average heights of skyscrapers. Rather, average heights are determined by the cyclical factors that affect the costs and benefits of construction. In short, if ego was a driving force of the skyline, we would expect to see a trend component to height and completions as builders react to what they see around them. The data do not support this.
2. In related tests, if builders were systematically aiming to stand out then the height of the skyline itself or the height of recent completions would be positively related to current average heights and completions. I do not find systematic evidence that builders are aiming to build above completed buildings.
3. More broadly, the simple market model provides a very good fit of both the number of completions and the height of these completions, which suggests that economic factors are the primary determinants of skyscrapers. Chow tests comparing the skyscraper market after World War II (post-1945) to pre-1946 do not indicate any structural breaks. This suggests, again, that, on average, economics is the driving force, because innovations after World War II would have allowed builders to build taller at less cost and thus more easily engage in height competition.

The rest of the article proceeds as follows. The next section reviews the relevant literature. The following section provides a brief review of the major economic and institutional factors that have affected skyscraper development in New York City. Then, I give a simple model for the market for height, with and without ego; the model is tested in the following section, which presents the results of the time-series regressions. Finally, I offer some concluding remarks. An appendix provides information about data sources and preparation.

Related Literature

Although there has been little work specifically on skyscrapers, there has been much detailed work on long-run urban real estate cycles. Early work such as that by Long (1936) and Hoyt (1933/2000) investigated major urban building cycles. Long (1936), for example, found two major cycles in Manhattan from 1865 to 1935, lasting 37 and 20 years, respectively. Hoyt detailed the value of Chicago land over 100 years, documenting roughly 18-year cycles, based primarily on the ebb and flow of population and businesses in Chicago. The major finding of these works is that urban building cycles undergo extended periods of boom and busts, with the peaks driven by an element of "speculative psychology" (Long 1936, p.190).

More recently, Wheaton, Baranski and Templeton (2009) have investigated long-run real estate prices in Manhattan from 1899 to 1999. They conclude that, though there have been wide swings in the prices of office buildings over the period, real estate values in the long run have been essentially flat. The findings of these works suggest that in the short run there are large profits or losses, but over the long run urban real estate markets return to a spatial equilibrium.

Over the last 25 years, there has been much work exploring the causes of real estate cycles, though none of this work explores the economics of building height. Much of the literature focuses on the debate on whether the real estate market is driven by myopic or rational expectations. The empirical evidence indicates that construction cycles behave in a way that is not compatible with builders having rational expectations, in the sense defined by Muth (1961). Work in this vein includes Wheaton (1987, 1999), Case and Shiller (1989) and Clayton (1996). Because of the strong evidence found in the real estate literature that construction and price behavior are more consistent with a myopic model rather than a rational expectations model, I use a simple "present-looking" model. As discussed later, this gives a very good fit to the data.[6]

[6] This is not to say that developers are not possibly using a rational expectations model or that they are not forward looking, but, based on the previous work discussed earlier, the results presented below and the work done in Barr (2007), the "present-looking" model appears to better describe the behavior of developers, given the fact that skyscraper

In recent years, there has been a series of papers that discusses the role of options pricing theory in the decision to build office space (Titman 1985, Grenadier 1995, Schwartz and Torous 2007, Holland, Ott and Riddiough 2002). One common theme of this work is that the value of the option to build depends on the level of building value uncertainty. An increase in uncertainty means that the relative value of vacant land will go up and, therefore, builders are less likely to commit to development.

In the vein of Holland, Ott and Riddiough (2002), a measure of "total uncertainty" (or uncertainty with respect to rent values) is created to test its effect on completions and height. As will be discussed later, because I do not have rent values, I use a proxy measure of economic activity that affects rents to look at how the standard deviation of this measure affects completions and height. For completions, I find that uncertainty has a negative effect but does not affect height.

Skyscraper Construction in Manhattan

The rise of an office-based economy during the mid to late 19th century and the tremendous population and economic growth of New York City generated a demand for building space to house offices and residences. By the late 19th century, the technological capabilities existed to supply this space, which needed to be in the form of highrise buildings. New York City's 1811 gridplan—which established a standard lot size of 25 ft $\times$ 100 ft—inadvertently caused relative land scarcity, by making assemblages for tall building more difficult (Willis 1995). Perhaps the two most important technological innovations were the elevator (and safety break) and the use of steel for building frames, which replaced heavy, load-bearing masonry (Landau and Condit 1996).

The first generation of skyscrapers were not subject to any height or bulk regulations; developers felt free to build very tall buildings that maximized the total rentable space by using as much of the plot area as possible (Willis 1995). Partly as a result of the emergence of skyscrapers, in 1916 New York City implemented the first comprehensive zoning legislation that stated height and use regulations for all lots in the city. In 1961, New York City implemented an updated zoning law.

Unlike Chicago, for example, New York has never directly capped the heights of buildings. Rather, the 1916 code created set-back requirements. That is,

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construction has long building lags, requires large capital investment and is semi-irreversible.

buildings had to be set back from the street based on some given multiple of the street width. The 1961 code put limits on the total building volume by setting so-called floor area ratios (FARs) in different districts.[7]

Because then there have been several adjustments to the regulations. For example, from 1982 to 1988, a special midtown zoning district was created to encourage development on the west side of midtown by allowing volume bonuses of up to 20%.[8]

Starting in the 1970s, a series of building-related subsidies were introduced to stimulate both business and residential construction. In 1977, the Industrial and Commercial Incentive Board (ICIB) was authorized to grant tax abatements to businesses if they constructed offices (or hotels) in New York City. Starting in 1984, the ICIB was disbanded and the program became the Industrial and Commercial Incentive Program (ICIP), which provided business subsidies "as of right," if the business satisfied a certain set of criteria. In the mid 1990s, the ICIP program was curtailed in Manhattan.

In terms of housing subsidies, in 1971 the "421-a" program was introduced to provide tax abatements to building developers for constructing apartments. For builders of rental units, the builder would qualify for the subsidies if he or she agreed to charge rents within New York City's rent stabilization program. Developers of condominiums could also qualify for the abatements, and the savings could then be passed to the buyers. The program was curtailed for most of Manhattan in 1985.

The Market for Skyscrapers

This section provides a simple, baseline model of the market for skyscrapers to generate equations for the equilibrium height and number of completions. This section assumes that status and ego are not relevant; in the next subsection, I alter the model to consider the effects of ego.

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[7] The FAR gives total building area as a ratio of the lot size. For example, a FAR of 10 means that total floor area can be ten times the lot area. Thus, a builder would have the choice of constructing a 10-story building that covers the entire lot or, say, a 20-story building that covers half the lot.

[8] The provision was also accompanied by restrictions on how much sunlight could be blocked by the top floors of the building, requiring that 75% of the sky surrounding a new building remain open.

A potential developer of a skyscraper faces the following profit function[9]:

$$\pi_t = V_t A_{t-n} M_{t-n} - C_{t-n} A_{t-n} \left(\frac{M_{t-n}}{A_{t-n}} \right)^2 - A_{t-n} L_{t-n}, \tag{1}$$

where $V_t = \sum_{\tau=t}^{\infty} \left(\frac{1}{1+r}\right)^{\tau} P_\tau$ is the per-square-foot value of the building at time t, the time a developer begins collecting income from the building, P_τ is the net rental price per square foot and r is the real discount rate. For the time being, take V_t as given.[10] Building decisions are made at time $t-n$. A_{t-n} is the area of the plot, M_{t-n} is the height of the building (in meters) and C_{t-n} measures the cost of construction. Finally, L_{t-n} is the cost of acquiring the land, per square foot.[11]

A developer will start reaping returns at time t for decisions made at time $t-n$, because there is a lag between the decision to build and when the building can start collecting rent. I assume, in accordance with CK, Picken and Ilozor (2003) and Sabbagh (1989), that building costs are quadratic with respect to height per square foot. This profit function represents that fact that, for a given plot size, the marginal costs of building higher are increasing, due to increased cost of elevators, HVAC systems, wind bracing and foundation preparation. The function also reflects the fact that a flat, bulky building is generally cheaper to build than a tall, narrow one of the same volume.

Given Equation (1), the first-order condition with respect to M_{t-n} yields a decision about the profit-maximizing height, which is a function of the value of the building and the building costs:

$$M^*_{t-n} = \frac{1}{2} \left(\frac{V_t A^2_{t-n}}{C_{t-n}} \right), \tag{2}$$

assuming that profits are greater than or equal to zero.

Next, I assume the standard zero-profit condition to determine the value of land. That is, the landowner will charge the developer a price for land such that there are no economic profits. If we set the profit equation (Equation (1)) equal to zero, substitute in Equation (2) and solve for L_{t-n}, we get the per-square-foot

[9] In this article, without loss of generality, I do not distinguish among the type of buildings. The data set here contains several types of buildings, including offices and apartment buildings. Barr (2008) investigates how use affects height.

[10] For the sake of simplicity I assume that each floor has the same value. In truth, rents are higher on higher floors, but here we can consider V_t to be the average rent per floor.

[11] In this article I assume A is exogenous. The empirical implications of this are discussed later. In addition, I assume that the developer builds on the entire plot.

value of land, which is based on the value of the building and the costs of building, as well as the plot size:

$$L^*_{t-n} = \frac{1}{4}\left(\frac{V_t^2 A_{t-n}^2}{C_{t-n}}\right). \tag{3}$$

Furthermore, I assume that the supply of plots that are available to developers to build on is a function of the value of the land at each period:

$$N_{t-n} = \gamma_0 \left(L_{t-n}\right)^{\gamma_1}. \tag{4}$$

Placing the right-hand side of Equation (3) into the right-hand side of Equation (4) gives an equation for the equilibrium number of skyscraper starts as a function of the costs and benefits of building:

$$N^*_{t-n} = \gamma_0 \left(\frac{V_t^2 A_{t-n}^2}{4C_{t-n}}\right)^{\gamma_1}. \tag{5}$$

In terms of the market for building space, I assume, as in Wheaton (1999), that the demand for building space is given by the following function[12]:

$$P_t = \alpha_0 D_t^{-\alpha_1} E_t^{\alpha_2},$$

where D_t is the quantity of space demanded, and E_t is the exogenously determined level of office employment.

Next, assume, similar to Wheaton (1999), that the short-run supply, that is, the current building stock at time t, S_t, is fixed so that the price is set to clear the market. This gives

$$P_t = \alpha_0 S_t^{-\alpha_1} E_t^{\alpha_2}. \tag{6}$$

Because I do not have data for rent, Equation (6) plays an important part in the analysis, because I will use building stock, employment and other demand variables to proxy for building rents.

For the reasons discussed in the literature review, I assume that building values are determined by the discounted value of the net rental price at time $t - n$ (*i.e.*, that developers use the current discount rate to determine the future value of a new building):

$$V_t = P_{t-n}/r_{t-n}, \tag{7}$$

[12] Without loss of generality, the model is simplified by having one variable that determines the quantity demanded and one that shifts demand. To reflect the particular characteristics of New York City, I include more variables in the empirical section later.

where r_{t-n} is the current real discount rate (which also includes depreciation). Substituting the right-hand side of Equation (6) for rent in Equation (7) gives the building value as

$$V_t = \frac{\alpha_0 S_{t-n}^{-\alpha_1} E_{t-n}^{\alpha_2}}{r_{t-n}}. \tag{8}$$

Finally, substituting the right-hand side of Equation (7) into Equations (2) and (5) gives estimatable equations for building height and starts, respectively:

$$M_{t-n}^* = \frac{\alpha_0}{2}\left(\frac{S_{t-n}^{-\alpha_1} E_{t-n}^{\alpha_2} A_{t-n}^2}{r_{t-n} C_{t-n}}\right), \tag{9}$$

$$N_{t-n}^* = \gamma_0 \left(\frac{\alpha_0}{4}\right)^{\gamma_1} \left(\frac{\left(S_{t-n}^{-\alpha_1} E_{t-n}^{\alpha_2}\right)^2 A_{t-n}^2}{r_{t-n} C_{t-n}}\right)^{\gamma_1}. \tag{10}$$

Because data exist only for the number of completions, I assume that the number of completions is equal to the number of starts $N_t = N_{t-n}$ and $M_t = M_{t-n}$.[13] Equations (9) and (10) are linear in log-log form.

The market model offers several testable hypotheses. We would expect to see, for example, that total building stock, constructions costs and interest rates have negatives coefficients, whereas employment and plot size have positive ones.

Ego and the Market for Height

Now assume that it is important for builders to have their buildings stand out in the skyline, either as a form of corporate advertising or as a manifestation of personal ego. In this case, we can assume that the return to building height is a function of both the profits it generates and the degree to which it can be seen within the skyline. Although HS offer a game-theoretic approach to the construction of the tallest building, here I explore how ego would affect the market in general. In essence I assume a less direct form of strategic interaction, where builders gain utility based on the ranking of their building in the height hierarchy. That is to say, the taller a building is relative to the other buildings in a city, the greater the satisfaction of the builder. This is a convenient simplification that allows us to move from the head-to-head model in HS to a market-wide one.

[13] Clearly, the number of completions can be less than the number of starts, but given the large costs of development, the irreversible nature of many construction-related decisions and based on the fact that many building completions occur well into an economic downturn, this assumption appears to be valid.

Assume now that builders have a utility function given by

$$u\,(M) = \pi\,(M) + \lambda f\,(M;\mu)\,,$$

where $\pi(M)$ is the profit from a building of height $M. f(M, \mu)$ is the contribution to utility based on a builder's relative height vis-à-vis the average height of the skyline, μ. The parameter $\lambda > 0$ measures the strength of ego (and it is assumed to be constant across builders and relatively small vis-à-vis $\pi(M)$).

Assume that $f(M;\mu)$ has the following form:

$$f\,(M;u) = \left(1 - \frac{\mu}{M}\right),$$

for $M > 0$. If $M = \mu$, then a builder gets no additional utility. If $M > \mu$, the builder receives positive utility; if $M < \mu$, the builder gets a utility loss.[14]

Notice a few properties of this functional form. First $\partial f/\partial M > 0$, which means that an increase in a builder's height increases utility; second $\partial f/\partial \mu < 0$, so that an increase in the mean, *ceteris paribus*, decreases utility. Finally $\partial^2 f/\partial M \partial \mu > 0$, which implies that the two variables are strategic complementarities as defined by Cooper and John (1988). In other words, as the average height of the skyline increases, a builder finds that increasing his or her own height increases marginal utility. If there is a keeping-up-with-the-Joneses effect, then we would expect to see strategic complementarities, because if builders do not add height to keep up then they will find that their buildings are more likely to get lost in the skyline. Although there are positive derivatives with respect to the mean height, I assume that a builder takes its value as given at time $t - n$. Thus, the strategic interaction, in essence, occurs over time and does not occur between the same players.

Given the functional form from Equation (1), utility is given by

$$u_t(M) = V_t A_{t-n} M_{t-n} - C_{t-n} A_{t-n} \left(\frac{M_{t-n}}{A_{t-n}}\right)^2 + \lambda \left(1 - \frac{\mu_{t-n}}{M_{t-n}}\right) - A_{t-n} L_{t-n}. \tag{11}$$

The first-order condition with respect to building height is

$$V_t A_{t-n} - 2\frac{C_{t-n}}{A_{t-n}} M_{t-n} + \lambda \frac{\mu_{t-n}}{M_{t-n}^2} = 0.$$

[14] The lack of symmetry around one would imply that the loss of utility from being less than the mean (*i.e.*, the degree of builder "shame") is greater than the sense of pride for being greater than the mean.

This function can be solved explicitly for M, although its form is relatively complicated. More importantly, however, the solution gives rise to an equilibrium height as a function of the model parameters:

$$M^*_{t-n} = M\left(V_t, A_{t-n}, C_{t-n}, \lambda, \mu_{t-n}\right),$$

assuming that $M^* > 0$. Via the Implicit Function Theorem, the derivatives can be signed. In particular, $\partial M^*/\partial \mu > 0$, $\partial M^*/\partial A > 0$, $\partial M^*/\partial V > 0$ and $\partial M^*/\partial C < 0$. Also notice that, similar to HS's model, the desire to build taller than the average height can dissipate profits, because utility maximization will move builders away from the profit-maximizing height.

Similarly to the non-ego model, I assume that utility is set to zero to determine land values as a function of equilibrium height:

$$L^*_{t-n} = \frac{1}{A} L\left[M\left(V_t, A_{t-n}, C_{t-n}, \lambda, \mu_{t-n}\right)\right]. \tag{12}$$

This function has the same derivatives as the equilibrium height function. Substituting Equation (12) into the supply equation (Equation (4)) gives the equilibrium number of skyscraper starts as a function of the economic fundamentals and the ego parameters

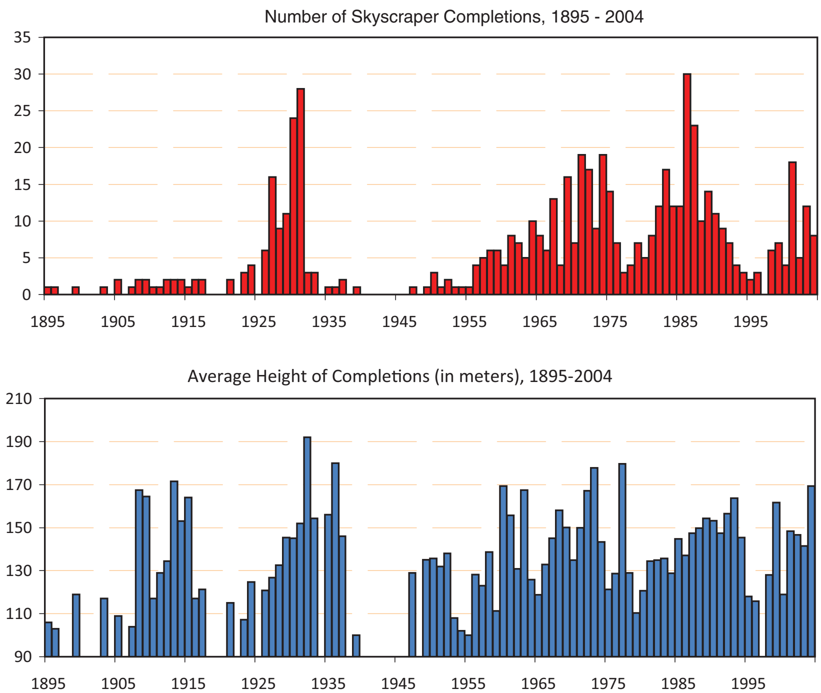
$$N^*_{t-n} = \gamma_0 \left(\frac{1}{A} L\left[M\left(V_t, A_{t-n}, C_{t-n}, \lambda, \mu_{t-n}\right)\right]\right)^{\gamma_1}.$$

Assuming, as earlier, that $N^*_t = N^*_{t-n}$, $M^*_t = M^*_{t-n}$ and $V_t = (\alpha_0 S^{-\alpha_1}_{t-n} E^{\alpha_2}_{t-n})/r_{t-n}$, the model gives rise to a set of testable hypotheses for building height and the number of completions. If the quest for status is important then the heights of buildings will be taller than otherwise. In particular, this model predicts that the average height of the skyline has a positive effect on both the number of completions and the heights of these completions.

Another implication of this ego model is that the average heights and completions of buildings, *ceteris paribus*, will be increasing because the quest for ego will introduce a type of height "arms race" over time, where new builders add extra height over the current mean, which is, presumably, rising over time. To test for this implication, I also include a time trend as a right-hand-side variable.

Furthermore, the parameter μ could be interpreted in a more narrow fashion. Rather than being the average height of all completed buildings, μ could represent the heights of recently completed buildings. That is to say, if developers are competing against their peers for status, then we would expect to see a positive relationship between the lag of average heights and current heights. I test for this by including the lag of heights as a right-hand-side variable.

Figure 1 ■ Annual time series of the number of skyscraper completions and their average heights in Manhattan, 1895–2004. See the Appendix for sources.



Finally, I perform a test for structural breaks in the coefficients. After World War II, new technological innovations were available, in theory, to build taller at less cost. For example, the use of glass facades made buildings lighter. Improvements in HVAC systems made height less of a concern, and new innovations in elevator management has made vertical transport less costly (*The Economist* 2006). These innovations would suggest that the cost of displaying ego would have gone down after the war, allowing developers easier means to build taller than the average heights around them.

Empirical Results

Figure 1 shows the time-series graphs over the period. The figure shows the cyclical nature of both the annual number of completions and the heights themselves, with average heights rising over the cycle. In terms of the number of completions of extremely tall buildings, the mid 1980s represents the most productive period, with the late 1920s/early 1930s coming in a close second.

The Data

The earlier model suggests equations for both the number of completions and the economic height of these buildings as a function of the lags of demand and supply variables. Similar to other works, I include office employment variables (see, *e.g.*, Kling and McCue 1987, Wheaton 1999), but I also include variables that relate directly to the New York City economy and which have not been explored elsewhere.

In several cases, time-series variables for New York City do not exist for the entire sample period of 1890 to 2004; in these instances, national variables are used. As will be demonstrated later, these variables are important determinants of skyscraper development in New York City. Although some variables, like interest rates, inflation and access to credit, may show regional differences (see, *e.g.*, Bodenhorn 1995), using national variables for New York City is legitimate because of the city's importance for the national economy, as well as its centrality in national financial markets.

In addition, clearly there has been technological innovation and improvements in building materials and methods over the 20th century. However, I do not have a direct measure of technological change. Rather I use an index of real building material costs, which, at least implicitly, measures the effect of technological change.[15]

Table 2 presents the descriptive statistics for the data used in the time-series regressions. In general, there are data for 115 years, 1890 to 2004. The dependent variables are observed from 1895 to 2004; additional years of data were acquired for the lags of the independent variables. For data about the buildings, I have the number of completions each year and the average height of the completions. The Appendix gives details on how these variables were constructed. As a measure of the total building stock I use the net cumulative number of completed skyscrapers. That is to say, the measure of total stock is the cumulative number of completions, with the number of destructions or demolitions removed in the year of the demolition or destruction. I also include the average area of the plots for the completed buildings.

For office employment, I use the proportion of total national employment that is in the Finance, Insurance and Real Estate industries (F.I.R.E./Emp.) (New York City employment data do not appear to exist over the entire sample period).

[15] For example, the index of real construction costs used here peaked in 1979. Between 1979 and 2003, real construction costs fell 15%. In 2003, the index was roughly the same value as it was in 1947.

Table 2 ■ Annual time-series descriptive statistics, 1890–2004.

Variable	Mean	SD	Min.	Max.	Obs.
Manhattan Skyscraper Variables					
Manhattan skyscraper completions	5.45	6.46	0.00	30.00	110
Avg. height of completions (m)	137.6	21.07	100	192	87
Avg. plot size (ft^2)	48,326	45,047	5,198	342,938	87
Net cumulative number of skyscrapers	193.6	183.7	0.0	586	115
Avg. height of skyline (m)	132.8	12.9	91.0	142.4	115
National Economic Variables					
Real construction costs index	1.28	0.267	0.862	1.70	115
Inflation, GDP deflator (%)	2.46	4.47	−17.30	18.93	114
Δ ln(value of real estate loans)	0.079	0.073	−0.165	0.352	114
F.I.R.E./total employment	0.044	0.015	0.018	0.066	115
Real interest rate (%)	2.29	4.73	−13.86	23.92	114
NYC Economic Variables					
Avg. Daily NYSE traded stock volume (M)	103.3	290.6	0.11	1456.7	115
Δ ln(Dow Jones industrial index)	0.046	0.213	−0.748	0.597	113
Pop.: NYC, Nassau, Suffolk, Westchester (M)	8.43	2.79	2.74	11.90	115
Economic volatility	2.47	1.35	0.437	6.52	111
NYC Dummy Variables					
Zoning Law Dummy (1916–2004)	0.774				115
“Westside” Zoning (1982–1988)	0.061				115
Indstl. & Comm. Incentive Prgrm. (1977–1992)	0.139				115
“421-a” Tax Abatement Prgm. (1971–1985)	0.130				115

Note: See the Appendix for sources.

Building costs are measured via an index of real construction material costs (a nominal building material cost index divided by the gross domestic product [GDP] deflator). To measure the access that developers have to capital, I use the annual growth rate of real estate loans provided by commercial banks; this is a measure of the willingness of banks to make loans, which is generally based on their belief about economic risk (see, *e.g.*, DePalma 1986, Hylton 1990). For the real interest rate I use the rate on commercial paper minus the current inflation rate, as determined by the GDP deflator.

The New York City metropolitan area population is clearly an important determinant of the demand for building space. Over the course of the 20th century, the region has become more decentralized. Although annual data exist for the New York City population, annual data for surrounding jurisdictions do not appear to exist (or are not accessible); as a result, decennial census data are used for the population of New York City and three counties in New York that supply a large fraction of workers and visitors: Nassau, Suffolk and Westchester.[16]

To measure the health of the New York economy, as well as the demand for building space, I use variables that relate to stock markets in New York: the annual average daily volume of stock trades on the New York Stock Exchange (NYSE) (a measure of the income available from stock trading) and the year-to-year change in the log of the Dow Jones Industrial Index, as a measure of stock market returns.

For subsidies and zoning policy, I have four variables. First, in terms of zoning, I include a dummy variable that takes on a value of one in years 1916–2004 to account for the presence of zoning regulations. In addition, I generate a *Westside* zoning dummy variable that takes on the value of one in the years 1982–1988. In these years, builders were given FAR bonuses which created an incentive to construct office space on the westside of Manhattan's midtown business district. In terms of building subsidies, I use a dummy variable that takes on the value of one in the years 1977–1992 to measure the effect of the business subsidies offered in those years. Finally, I include a *421-a* dummy variable that takes on a value of one in years 1971–1985 to reflect the relatively generous residential subsidies offered in this period. Note that, between the years 1982 and 1985, the three types of building incentive policies were simultaneously in effect. Thus, in the years between 1984 and 1987 we would expect to see a flurry of skyscraper activity.

Finally, the variable *economic volatility* was a derived variable designed to measure the volatility of building values. The variable is generated from eight variables that measure the health of the New York City economy.[17] Each of the variables was normalized by subtracting its mean and dividing by the standard deviation (*i.e.*, turned into a z score). The four "bad" variables were then made negative, and all the z scores were added together to create an economic activity index. The mean of this index is 0.0015, and the standard deviation is 3.11. Any value above zero indicates a robust New York City economy; anything

[16] Note that New York City before 1898 did not include the city of Brooklyn. The populations of what were to become the five boroughs of New York City are included in 1890.

[17] These variables are: (1) Nominal commercial paper rate, (2) the GDP deflator inflation rate, (3) the percent change in the Dow Jones Industrial Index, (4) the percent change in the NYSE trading volume, (5) the New York City property tax rate, (6) the ratio of national F.I.R.E. employment to total employment, (7) the national unemployment rate and (8) the growth in the equalized assessed values of land in Manhattan. Descriptive statistics are available upon request.

below is a weak one. The volatility measure was derived by taking the standard deviation of the economic index for each year and the prior 2 years. Thus the volatility variable is a type of moving average, designed to measure the average variation in economic activity and hence building values for a 3-year period.

In this study I assume that plot size is a randomly determined, exogenous variable. Builders, however, may seek out large plot sizes so they can build tall buildings because it is more efficient to build on larger plots. Therefore the inclusion of plot size introduces a possible trade-off. On one hand its omission might bias the coefficients of the included variables, but on the other hand, it may come at the expense of including an endogenous one.

In the end, however, I included the average plot size. From a theoretical point of view, the lot size places an important constraint on the economics of skyscraper construction. Smaller plots make skyscrapers more costly to construct, thus it is important to measure (even if imperfectly) the degree to which this variable helps determine skyscraper outcomes.

Second, from the point of view of introducing a selection bias, it is not clear that plot size is in fact endogenous. The exogenous factors that determine the size and nature of the plot are many. For example, in lower Manhattan there are many odd-shaped and small lots and blocks. These blocks were created in the early years of New York's history. Landowner holdouts are not uncommon, and they force developers to work with smaller or nonrectangular plots.[18] Finally, in Barr (2008), using Hausman's specification test, I test for plot exogeneity at the building/plot level and do not find evidence of endogeneity. With plot-level data, I am able to use the size of the city block as an instrument. Block sizes were, in general, determined in 1811 and thus are strictly exogenous. In addition, block sizes affect the possible lot sizes but are not a determinant of building height.

For these reasons, I have included the annual average plot sizes in the regressions. With regard to completions, omission of the plot size variable appears to cause an estimation bias in a few of the variables; most notably the effect of zoning on skyscraper completions appears to be implausibly large without controlling for plot size. With regard to height, the omission of plot size has a varied effect on the other coefficients, depending on the estimation procedure used.

[18] In Barr (2008), I find that perfectly rectangular plots constitute only about 45% of skyscraper plots.

Regression Results

Generally speaking, after a developer acquires a plot of land, he or she will then draw up architectural plans and make decisions about the building's potential height, volume, use and architectural style. The developer will also then acquire financing for the project either in the form of investment equity and/or a construction loan. After the building is completed, a long-term mortgage is taken out to pay off the construction loan. This process from start to finish can take several years. To the best of my knowledge, there are no prior studies that investigate the lag lengths for skyscrapers. However, in a sample of 114 buildings completed throughout the 20th century, and embedded within the time-series here (data available upon request), I compared the year of completion to the year of building permit issuance. The mean time between the two is 2.4 years, with a standard deviation of 1.3 years (the median is 2 years).

To empirically ascertain the lag lengths for the different variables, in the vein of Wheaton (1999), starting with lag lengths of 5 years prior to completion, regression results were compared to other regressions with different lag lengths to see which equations had the best overall fit, in terms of adjusted R^2. In the end, lag lengths for the equations varied between 1 and 4 years. In general, those variables that related to the demand for building space had shorter lag lengths than those that related to financing, which makes sense given that builders must first secure financing before beginning construction. The factors that go into initial planning and land acquisition can take much longer, but exploring these lengths is beyond the scope of the article.

Number of Completions

Table 3 presents the regressions for the annual number of completions. The dependent variable is the log of one plus the number of completions.[19] Equation (1) looks at the economic and policy determinants of completions with the omission of the plot size variable. Equation (2) is the same as Equation (1) but with plot size included. Equations (3)–(5) test the ego hypothesis. Equation (3) includes the year to test for a time trend; Equation (4) includes the average skyline height, lagged 3 years; and Equation (5) includes the lag of the annual average completions (interacted with a dummy variable for at least one completion).

Economic and Policy Variables

In general, these regressions show a good fit to the data, and the coefficients show the expected signs; this offers strong empirical validation of the market

[19] For simplicity, the results of ordinary least squares rather than Poisson regressions are given. The results are quite similar.

Table 3 ■ Dependent variable $\ln(1 + Number\ of\ Completions)$

	(1)	(2)	(3)	(4)	(5)
$\ln(F.I.R.E./Emp)_{t-2}$	4.53	2.91	2.85	2.78	2.75
	(6.46)***	(5.13)***	(5.43)***	(5.48)***	(4.70)***
$\ln(Total\ Stock)_{t-2}$	−2.76	−2.18	−2.14	−1.99	−2.15
	(9.69)***	(9.31)***	(9.45)***	(8.80)***	(9.09)***
$\ln(Construction\ Costs)_{t-2}$	−2.89	−2.71	−2.37	−2.88	−2.72
	(4.93)***	(4.90)***	(4.00)***	(5.4)***	(4.81)***
$\ln(NYSE\ Volume)_{t-2}$	0.161	0.173	0.246	0.148	0.176
	(3.46)***	(5.16)**	(2.24)**	(3.77)***	(5.24)**
$\ln(NYC\ Area\ Pop.)_{t-2}$	10.38	8.05	8.40	7.97	8.01
	(9.34)***	(8.23)***	(6.74)***	(8.45)***	(8.40)***
$Zoning_{t-2}$	−1.18	−0.216	−0.257	−0.154	−0.151
	(4.45)***	(1.03)	(1.07)	(0.731)	(0.64)
$\Delta \ln(R.E.\ Loans)_{t-3}$	2.19	1.73	1.75	1.86	1.71
	(3.87)***	(3.85)***	(3.80)***	(4.05)***	(3.78)***
$\Delta \ln(DJI)_{t-3}$	0.858	0.593	0.554	0.619	0.597
	(3.24)***	(2.48)**	(2.81)***	(2.99)***	(2.75)***
$Real\ Interest\ Rate_{t-4}$	−0.026	−0.018	−0.017	−0.018	−0.018
	(1.64)	(2.19)**	(2.16)**	(2.28)**	(2.25)**
$Volatility\ Index_{t-2}$	−0.153	−0.133	−0.138	−0.120	−0.127
	(2.74)***	(3.22)***	(3.22)***	(3.44)***	(3.18)***
$Westside\ Zoning_{t-2}$	0.440	0.483	0.474	0.478	0.489
	(2.23)**	(2.32)**	(2.32)**	(2.29)**	(2.33)**
$ICIP_{t-2}$	0.641	0.587	0.611	0.574	0.585
	(3.02)***	(2.95)***	(3.14)***	(2.86)***	(2.89)***
421-a_{t-2}	0.480	0.441	0.442	0.451	0.438
	(4.16)***	(3.61)***	(3.69)***	(3.62)***	(3.53)***
$\ln(Avg.\ Plot\ Size)_t$		0.085	0.082	0.086	0.084
		(7.85)***	(6.46)***	(8.32)***	(7.47)***
$Year_{t-2}$			−0.012		
			(0.69)		
$\ln(Avg.\ Skyline\ Height)_{t-3}$				−2.14	
				(1.85)*	
$\ln(Avg.\ Height)_{t-3}$					0.020
					(1.00)
Constant	−137.7	−110.2	−95.0	−99.4	−110.4
	(4.21)***	(7.59)***	(4.11)***	(6.37)***	(7.66)***
Observations	107	107	107	107	107
R^2	0.80	0.88	0.88	0.88	0.88
$\bar{R}^2$	0.77	0.86	0.86	0.86	0.86
Durbin–Watson	2.28	2.00	2.00	2.02	2.01

Note: Absolute values of Newey-West *t*-statistics are in parentheses. *Significant at the 10%; **significant at the 5%; ***significant at the 1%.

model presented above. Furthermore, the results provide evidence that the main driver of overbuilding is myopic expectations rather that other strategic factors. Over the course of the 20th century, skyscraper building activity has been quite sensitive to both employment in F.I.R.E., and the New York City regional population, with the number of completions being elastic with respect to these variables. Stock market growth and trading volume are also important determinants of completions, but they have relatively inelastic effects.

On the supply side, real building material costs significantly affect construction, with their effects being elastic. In terms of financing, interest rates appear to have modest negative effects on construction. However, the access that developers have to real estate capital, as measured by the growth of real estate loans provided by U.S. banks, appears to be a relatively stronger determinant of building construction. Finally, total volatility appears to be a negative determinant of completions, as would accord with the findings in the options literature, such as Holland, Ott and Riddiough (2002).

In addition, government policies have been important for both construction and height. The coefficient on the *zoning* variable (= 1 if after 1915, 0 otherwise) is negative, as would be predicted, but, interestingly, it is not statistically significant. The effect of zoning would be to presumably make buildings shorter, on average, and would therefore reduce the number of completions of very tall buildings. The coefficients show, however, that this effect appears to be relatively large, decreasing completions by about 15%. An F test comparing separate zoning dummy variables for the 1916 and 1961 zoning regulations, respectively, did not show statically significant differences, and thus only one dummy variable was included. The Westside zoning plan implemented in the mid 1980s to generate more office development appears to have been a very successful program, increasing the total number of completions by close to 50% during that period.

Furthermore, property tax subsidies, designed to increase office employment and housing, have had an important impact on skyscraper construction since the mid 1970s. The evidence indicates that housing subsidies (the *421-a* program) and business subsidies (the ICIP) appear to have increased the number of skyscrapers by close to 100% more than would have been built otherwise during the periods in which both of them were simultaneously in effect. The combined effect of all three incentive programs (in effect between 1982 and 1985) appears to have increased the total number of skyscrapers in that period by close to 150% above what it would have been otherwise. This helps to account for the construction peak in the mid 1980s.

Ego Variables

The estimated coefficients that test the ego hypothesis either do not show statistical significance or have the wrong sign. Equation (3) shows that, *ceteris paribus*, there has been no time trend in the number of completions. Equations (4) and (5) indicate that past heights do not seem to matter. In fact, the coefficient for the average skyline height is negative. There is no significance for the lag of heights on completions. Finally, a Chow test was performed based on Equation (2) in Table 3, testing for a structural break after World War II (after 1945). The value of the F statistic was 0.559, with a probability value of 0.897. This indicates that the determinants of completions were the same in the two periods.

Table 4 ■ Dependent variable: ln(*Average Height*)

	(1)[%]	(2)[a]
$\ln(F.I.R.E./Emp.)_{t-1}$	0.096 (0.53)	0.336 (2.19)**
$\ln(Total\ Stock)_{t-2}$	−0.210 (2.70)***	−0.167 (2.50)**
$\ln(Construction\ Costs)_{t-2}$	−0.630 (3.69)***	−0.460 (3.13)***
$\ln(NYSE\ Vol.)_{t-2}$	0.036 (2.49)**	0.017 (1.41)
$\ln(NYC\ Area\ Pop.)_{t-1}$	1.24 (3.89)***	0.866 (2.51)**
$Zoning_{t-1}$	−0.269 (2.59)**	−0.280 (3.56)***
$\Delta \ln(R.E.\ Loans)_{t-2}$	−0.501 (2.38)**	−0.333 (1.71)*
$\Delta ln\ (DJI)_{t-1}$	−0.078 (1.39)	−0.147 (2.80)***
$Real\ Interest\ Rate_{t-2}$	−0.004 (1.17)	−0.008 (2.64)***
$Westside\ Zoning_{t-1}$	−0.033 (1.04)	0.013 (0.30)
$ICIP_{t-1}$	0.227 (3.83)***	0.131 (1.99)**
$421\text{-}a_{t-1}$	−0.082 (3.25)***	−0.051 (1.39)
$\ln(Avg.\ Plot\ Size)_t$	0.137 (5.16)***	0.087 (4.34)***
$At\ Least\ One\ Completion_t$		3.95 (18.9)***
Constant	−15.1 (2.968)***	−11.8 (2.16)**
Observations	87	110
R^2	0.53	0.997
$\bar{R}^2$	0.44	0.997
Durbin–Watson	1.60	1.76

Note: [%] Variables in each year are weighted by the inverse of the square root of number of completions; years with no completions for dependent variable were dropped. Absolute values of robust *t* statistics are in parentheses.
[a] Absolute values of Newey-West *t* statistics are in parentheses. *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

Height

Tables 4–6 present the height equation results. Table 4 gives the results when the dependent variable is in logarithmic form. Equation (9), for example, implies that the economic height is linear in log–log form. However, the results of regressions when average height is in levels—given in Table 5—appear to have a better fit of the data. Thus, both sets of results are given.[20]

[20] Note that the volatility variable was dropped from the height equations because it was highly insignificant across all specifications.

Table 5 ■ Dependent variable: *Average Height* (m)

	OLS[%]	Tobit[a]	Heckman[b]
	(1)	(2)	(3)
$(F.I.R.E./Emp.)_{t-1}$	1,222 (2.37)**	40.2 (1.30)	1127 (1.45)
$\ln(Total\ Stock)_{t-2}$	−21.9 (2.46)**	−28.3 (2.61)***	−24.4 (1.94)*
$\ln(Construction\ Costs)_{t-2}$	−66.1 (3.52)***	−72.0 (3.09)***	−75.5 (3.27)***
$\ln(NYSE\ Vol.)_{t-2}$	0.941 (0.50)	3.31 (1.91)*	1.31 (0.58)
$\ln(NYC\ Area\ Pop.)_{t-1}$	120.6 (2.68)***	145.9 (3.07)***	142.5 (2.45)**
$Zoning_{t-1}$	−35.3 (4.02)***	−40.0 (3.00)***	−39.1 (2.95)***
$\Delta \ln(R.E.\ Loans)_{t-2}$	−43.7 (1.70)*	−51.3 (1.68)*	−51.9 (1.59)
$\Delta ln\ (DJI)_{t-1}$	−20.3 (2.70)***	−22.6 (2.75)***	−23.7 (2.85)***
$Real\ Interest\ Rate_{t-2}$	−1.22 (2.62)***	−1.11 (1.90)*	−1.22 (2.08)**
$Westside\ Zoning_{t-1}$	0.398 (0.07)	−0.181 (0.03)	0.864 (0.11)
$ICIP_{t-1}$	16.0 (1.75)*	23.5 (2.86)***	18.0 (1.92)*
$421\text{-}a_{t-1}$	−6.49 (1.26)	−8.41 (1.59)	−6.66 (1.22)
$\ln(Avg.\ Plot\ Size)_t$	11.7 (4.40)***	16.4 (11.96)***	11.7 (3.44)***
$At\ Least\ One\ Completion_t$	8.13 (0.29)		
Constant	−1837 (2.69)***		−2162 (2.42)**
Mills λ			−1.15 (0.12)
Observations	110	110	110
R^2	0.94	0.31	
Adj. R^2/P value Wald χ^2	0.93		0.00

Note: [%]Absolute values of Newey-West t-statistics are in parentheses. [a]Marginal effects of coefficients given. Absolute values of z statistics are in parentheses. [b]Absolute values of z statistics are in parentheses. *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

In terms of estimation methods, a few words are in order. Because for some years there were no completions of skyscrapers, there are no height observations for those years. In Table 4, Equation (1) is the result of regression where each observation is weighted by the inverse of the square root of the proportion of completions in that year, which can be appropriate when dealing with variables that are averages (and this also has the effect of removing the years for which no observations exist). Equation (2) is produced by OLS, but with the inclusion of a dummy variable for the years in which their were no completions.

Table 6 ■ Dependent variable: *Average Height* (meters)

	OLS (1*a*)	Tobit (1*b*)	OLS (2*a*)	Tobit (2*b*)	OLS (3*a*)	Tobit (3*b*)
$(F.I.R.E./Emp.)_{t-1}$	1,129	37.0	1,118	26.5	844.8	25.3
	(2.12)**	(1.19)	(2.00)**	(0.82)	(1.52)	(0.81)
$\ln(Total\ Stock)_{t-2}$	−20.2	−26.6	−18.4	−16.2	−16.5	−23.5
	(2.22)**	(2.41)**	(1.76)*	(1.12)	(1.81)*	(2.16)**
$\ln(Construction\ Costs)_{t-2}$	−48.9	−56.0	−68.6	−81.2	−58.7	−63.6
	(2.10)**	(1.81)*	(3.53)***	(3.35)**	(2.80)***	(2.75)***
$\ln(NYSE\ Vol.)_{t-2}$	4.24	6.23	0.663	1.70	1.31	3.68
	(1.42)	(1.51)	(0.35)	(0.80)	(0.73)	(2.15)**
$\ln(NYC\ Area\ Pop.)_{t-1}$	132.5	155.0	116.5	134.9	94.0	114.6
	(2.81)***	(3.19)***	(2.56)**	(2.83)***	(2.06)**	(2.35)**
$Zoning_{t-1}$	−36.9	−40.7	−33.6	−37.8	−27.3	−26.3
	(4.08)***	(3.06)***	(3.38)***	(3.83)***	(3.23)***	(1.8)*
$\Delta \ln(R.E.\ Loans)_{t-2}$	−46.3	−51.2	−40.7	−43.7	−43.3	−44.3
	(1.77)*	(1.68)*	(1.54)	(1.42)	(1.68)*	(1.47)
$\Delta ln\ (DJI)_{t-1}$	−18.5	−20.7	−20.1	−22.0	−18.6	−19.7
	(2.57)**	(2.44)**	(2.75)***	(2.69)***	(2.45)**	(2.41)**
$Real\ Interest\ Rate_{t-2}$	−1.18	−1.03	−1.19	−0.900	−1.10	−0.996
	(2.50)**	(1.74)*	(2.55)**	(1.48)	(2.38)**	(1.73)*
$Westside\ Zoning_{t-1}$	−0.111	−0.888	0.399	−0.348	1.19	0.031
	(0.02)	(0.11)	(0.07)	(0.04)	(0.20)	(0.03)
$ICIP_{t-1}$	16.4	23.6	15.9	22.7	14.3	21.1
	(1.75)*	(2.88)**	(1.74)*	(2.79)***	(1.52)	(2.60)**
$421\text{-}a_{t-1}$	−5.67	−7.70	−6.82	−8.18	−6.45	−8.44
	(1.06)	(1.44)	(1.66)*	(1.56)	(1.24)	(1.63)
$\ln(Avg.\ Plot\ Size)_t$	11.5	16.15	11.8	16.2	11.5	16.4
	(5.06)***	(4.1)***	(4.39)***	(12.59)***	(4.33)***	(12.1)***
$At\ Least\ One\ Completion_t$	9.38		7.32		10.4	
	(0.33)		(0.26)		(0.37)	
Year	−0.491	−0.440				
	(1.31)	(0.78)				
$Avg.\ Skyline\ Height_{t-2}$			−0.254	−0.721		
			(0.50)	(1.25)		
$Avg.\ Height_{t-1}$					0.052	0.081
					(1.81)*	(2.04)**
Constant	−1126		−1745		−1441	
	(1.32)		(2.49)**		(2.08)**	
Observations	110	110	110	110	110	110
R^2	0.94	0.31	0.94	0.31	0.94	0.31
Adj. R^2	0.93		0.93		0.94	

Note: OLS equations have absolute values of Newey-West t-statistics in parentheses. The Tobit equations present the marginal effects of the coefficients. Absolute values of z-statistics are in parentheses. *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

In the vein of Welch (1973), to control for the years in which there are no completions and to get a better estimate of the effect of the independent variables, I include a dummy variable that takes on one if there are no completions, zero otherwise. Note that the presence of the dummy variable inflates the value of R^2. The reason it jumps from close to 0.5 to close to one is primarily because of the increased variation in the dependent variable; the R^2 of Equation (1) offers better measures of explanatory power.

Table 5 presents three different equations with the dependent variable in levels. As a robustness check, as well as for a check on the consistency of the estimates, the results of three types of estimation procedures are given. The first equation is estimated via OLS with the inclusion of a dummy variable for at least one completion. Equation (2) is estimated using the Tobit procedure to account for the zero height observations.[21] The table gives the marginal effects to make them comparable with the OLS results. Finally, Equation (3) is estimated via a two-step Heckman procedure. Here the assumption is that the zero height observations represent a kind of sample selection issue. Skyscraper height is only observed if at least one is built; those years with no observations suggest that developers have opted out of the very tall skyscraper market for reasons due to depressions, wars and other economic factors, or smaller skyscrapers of less than 100 m were built, but not observed. The first stage is a probit regression which estimates the probability of at least one completion.[22] The three equations (OLS, Tobit and Heckman) give similar results. Note, however, that the z statistic for the Mills ratio is not statistically significant, indicating there is no sample selection issue.

Finally, Table 6 shows the results of the height equations with the tests of the ego hypothesis. For each variable, two models are presented. The first is estimated via OLS with the inclusion of a dummy variable for at least one completion, and the second gives the results from the Tobit estimation procedure.

Economic and Policy Variables. In terms of lag lengths we can see that the demand variables have the best fit with lags of 1 or 2, whereas the "decision to supply" variables have optimal lags of 2 years. That the lag structure is a bit different for the height equation as compared to the completions equation is most likely due to the fact that height adjustments can be made during the course of the project, though not without some costs to the builders.

Most, but not all, of the economic variables have the correct signs and are statistically significant. Across equations, as expected, we see that F.I.R.E. employment is positively related to height (though there are large differences in estimates across estimation methods). The New York City area population is also important in generating the demand for height. Stock exchange volume appears to have a very modest, but positive, effect on height.

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[21] One can think profit as being a "latent" variable, and height is a continuous variable given that profit is non-negative.

[22] The probit equation for the Heckman model is available upon request. The probit right-hand-side variables are the same as the variables in the completions equations.

On the supply side, both construction costs and total building stock negatively affect height, as would be expected. Similar to the completions equations, interest rates do not strongly determine height, although the variable is statistically significant across several specifications.

Interestingly, and unexpectedly, the growth in real estate loans appears to be negatively related to height (but positively related to completions). Perhaps builders use the extra supply of money toward building more projects rather than taller ones. Similarly, the growth rate in the Dow Jones Industrial Index also appears to be negatively related to height, perhaps for the same reason as the growth in real estate loans. Investigating the reasons for these negative signs are left for future work.

The presence of zoning laws appears to have reduced building heights by a large percentage, close to 30% (or about 40 m, on average), as compared to the years before zoning regulations were in place. As discussed above, zoning regulations were initially put into effect to limit shadows and density, rather than height *per se*. However, limiting the amount of buildable space adds extra costs.

In general, the policy-related variables have mixed effects on height, with no effect from the Westside zoning change. The ICIP appears to have significantly increased the height of the skyline, whereas the 421-a tax abatement program slightly reduced it. The reason is most likely that they created an incentive for many new residential buildings, which tend to be less tall on average as compared to other types of skyscrapers (see Barr 2008).

Ego Variables. Table 6 presents the results of the tests for the ego hypothesis. First, Equations (1a) and (1b) test for a time trend. The estimates and t statistics show no evidence of this. Second, Equations (2a) and (2b) include the lag of the average skyline height; again no evidence is found for an effect. Then, Equations (3a) and (3b) include the lag of average heights (interacted with a dummy for at least one completion.) Here we see a statistically significant and positive effect from the coefficients. However, the coefficient estimate appears to be too small to provide strong evidence for the ego hypothesis. For example, Equation (3a) suggests that for every one meter increase in the lag of average height, there is an increase in the average skyline by 0.052 m. If strategic interaction were present at the market level, one would expect, for example, that each 1-m increase in the skyline would be matched by a 1-m increase in heights. Finally, a Chow test comparing the coefficient estimates after 1945 to those before 1946 shows no structural break. The F statistic from Table 5, Equation (1) is 0.523, with a probability value of 0.920.

Conclusion

This article has presented an econometric analysis of the determinants of skyscraper construction and heights in Manhattan from 1895 to 2004. Using a new data set I am able to test the aggregate, market-wide implications of two hypotheses about skyscrapers. The CK hypothesis stipulates that extremely tall buildings are the result of the cost and benefits of building tall. Expensive land costs and small plot sizes promote the skyscraper as a "machine that makes the land pay" (Gilbert 1900, p. 624). On the other hand, HS hypothesize that extremely tall buildings are due, in part, to ego promotion and the resulting strategic interaction among builders. Although those works focus on particular examples of skyscrapers, the work here investigates how these two forces—profit maximization and ego—operate in the aggregate.

First, I provided a baseline model for the market for height and the number of completions. Then I extend the model to include the effects of ego. If builders seek to stand out in the skyline, then we would predict a positive relationship between the average height of the skyline and current heights and completions.

To test for the ego hypothesis, I perform four tests. First, I test for a time trend in both completions and heights; I do find not any evidence of this. Second, I test for an effect from the lag of the average skyline height, and I do not find a positive effect from this either. Third, I test the effect of the lag of average height on current completions and average height. I find that lagged height has no effect on completions, but has a very small and positive effect on height, though the estimated coefficient size appears too small to be driven by competition. Finally, I perform a Chow test for completions and average heights by comparing the coefficients before and after World War II to see if there were structural breaks in the skyscraper market that may have been driven by technological change; I find no evidence for a structural break. Finally, the significance of several important economic and political variables provide strong evidence that profit maximization is driving building height, on average.

The results here suggest that strategic interaction has not been a systematic driving factor in skyscraper height in aggregate in the Manhattan height market. As HS document, some builders clearly aim to project their egos onto the skyline and some corporations aim to advertise themselves via their headquarters. But within a city not all builders have access to the largest plots that enable them the opportunity to stand out. As well, there are many periods in New York's history when the economics were not favorable to building tall, in general.

Record-breaking height, in particular, appears to be due to the right combination of ego and economics, and thus the frequency with which records will be broken are statistically rare events, not related to the everyday skyscraper market. Since 1890, for example, a New York City height record has been broken only 11 times, and seven of those occurred before 1920. No record has been surpassed within the city since 1973.[23]

In short, the projection of ego onto the skyline appears to occur only when the opportunity cost of ego is relatively low. More work needs to be done to determine both the costs and benefits of ego expression as well as the nature of market conditions that can make ego an important variable.

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[23] This total record break count includes the first skyscraper in New York and counts only one of the Twin Towers.

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Appendix: Data Sources and Preparation

(1) *Skyscraper height, year of completions and current status (extant or not), net total stock and average skyline height*. The primary sources are emporis.com and skyscraperpage.com, which provide information on the height, year of completion and status (demolished or not). As of June 2008, the websites listed 599 buildings in Manhattan that are 100 m or taller; these buildings could be of any type, including for office, apartment and mixed uses. I aggregated the data to generate the number of completions per year, the average height of those completions for each year and the total net cumulative number of completions. The year of demolition or destruction (if applicable) was found from articles from the historical New York Times (Proquest). Average skyline height is calculated by taking the annual cumulative total net height of all completions divided by the net number of total completions. Values for 1890 to 1894 were given 91, 93, 95, 97 and 99, respectively.

(2) *Average plot size*. Plot sizes come from the NYC Map Portal (http://gis.nyc.gov/doitt/mp/Portal.do), Ballard (1978), http://www.mrofficespace.com/ and the NYC Dept. of Buildings Building Information System (http://a810-bisweb.nyc.gov/bisweb/bsqpm01.jsp).

(3) *Real construction cost index*. Index of construction material costs: 1947–2004: Bureau of Labor Statistics Series Id: WPUSOP2200 "Materials and Components for Construction," (1982=100). 1890–1947: Table E48 "Building Materials," *Historical Statistics* (1926=100). To join the two series, the earlier series was multiplied by 0.12521, which is the ratio of the new series index to the old index in 1947. The Real index was create by dividing the construction cost index by the GDP Deflator for each year.

(4) *Inflation*. 1890–2004: GDP Deflator (2000=100).

(5) *Value of real estate loans*. 1896–1970: Table X591, "Real Estate Loans for Commercial Banks," *Historical Statistics*. 1971–2004: FDIC.gov Table CB12, "Real Estate Loans FDIC-Insured Commercial Banks." The two series were combined without any adjustments. For 1890–1895, values are generated by forecasting backward based on an $AR(3)$ regression of the percent change in real estate loans from one year to the next.

(6) *Finance, insurance and real estate employment (F.I.R.E.)/total employment*. 1900–1970: F.I.R.E. data from Table D137, *Historical Statistics.* Total (non-farm) Employment: Table D127, *Historical Statistics*. 1971–2004: F.I.R.E. data from BLS.gov Series Id: CEU5500000001 "Financial Activities." Total non-farm employment 1971–2004 from

BLS.gov Series Id:CEU0000000001. The earlier and later employment tables were joined by regressing overlapping years that were available from both sources of the new employment number on the old employment numbers and then correcting the new number using the OLS equation; this process was also done with the F.I.R.E. data as well. 1890–1899: For both the F.I.R.E. and total employment, values were extrapolated backward using the growth rates from the decade 1900 to 1909, which was 4.1% for F.I.R.E. and 3.1% for employment.

(7) *Real interest rate (nominal rate minus inflation)*. Nominal interest rate: 1890–1970: Table X445 "Prime Commercial Paper 4–6 months," *Historical Statistics,* 1971–1997, http://www.federalreserve.gov. 1998–2004: six-month CD rate. Six-month CD rate was adjusted to a CP rate by regressing 34 years of overlapping data of the CP rate on the CD rate and then using the predicted values for the CP rate for 1997–2004. Inflation is the percentage change in the GDP deflator.

(8) *Average daily NYSE traded stock volume*. http://www.nyse.com/.

(9) *Dow Jones industrial index (closing value on last day of year)*. 1896–1932: Table Cj804, *Historical Statistics Millennial Edition Online*. 1933–2004, Yahoo.com. 1891–1895: Generated "backward" from predicted values based on a regression of the percent change in DJI on percent change of Standard & Poors Index (Table Cj800), Commercial Paper Rate and Percent change in Non-Ag. Employment Growth.

(10) *NYC Property Tax Rates (per* $*100 total assessed value)*. 1890–1975: Various volumes of the *NYC Tax Commission Reports*. 1976–2004: NYC Department of Finance website. Note that in 1983 tax rates became different for different types of properties; the rates used here are for commercial property.

(11) *Annual NYC population*. 1890–1959: Various annual reports of the NYC Health Department. 1960–2004: NYC Department of Health website (http://home2.nyc.gov/html/doh/downloads/pdf/vs/2005sum.pdf).

(12) *Population NYC, Nassau, Suffolk and Westchester*. 1890–2004: Decennial Census on U.S. Population volumes. Annual data is generated by estimating the annual population via the formula $pop_{i,t} = pop_{i,t-1}e^{\beta_i}$, where i is the census year, that is, $i \in \{1890, 1900, \ldots, 2000\}$, t is the year, and β_i is solved from the formula, $pop_i = pop_{i-1}e^{10*\beta_i}$. For the years 2001–2004, the same growth rate from the 1990s is used.

(13) *Equalized assessed land value for Manhattan*. 1890–1975: Various volumes of *NYC Tax Commission Reports*. 1975–2004: Real Estate Board

of NY. *Equalization Rates*, 1890–1955: Various volumes of *NYC Tax Commission Reports*. 1955–2004: NY State Office of Real Property Services.

(14) *U.S. Unemployment Rate*. 1890–1970, Table D85, *Historical Statistics*. 1971–2004: Bls.gov Table LNU04000000.