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SKYSCRAPERS AND SKYLINES: NEW YORK AND CHICAGO, 1885–2007*

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ABSTRACT. This paper investigates skyscraper competition between New York City and Chicago. The urban economics literature is generally silent on strategic interaction between cities, yet skyscraper rivalry between these cities is a part of U.S. historiography. This paper tests whether there is, in fact, strategic interaction across cities. First, I find that each city has positive reaction functions with respect to the other city, suggesting strategic complementarity. In regard to zoning, I find that height regulations negatively impacted each city, but produced positive responses by the other city, providing evidence for strategic substitutability.

The character and quality of any city can be told from a great distance by its skyline, but these buildings do more than advertize a city. They show the faith of many in its destiny, and they create a like faith in others (Shultz and Simmons, 1959, p. 12).

1. INTRODUCTION

Since the late-1880s NewYork and Chicago have been two of the world's premier skyscraper cities. By 1929, New York and Chicago contained 68 percent of the nation's buildings that were 20 stories or taller (Weiss, 1992). Currently, New York and Chicago hold 56.6 percent of the nation's buildings that are 239 m (785 ft) or taller. Of the 10 current tallest buildings in the United States, four are in Chicago and four are in New York (six would be in New York, if the Twin Towers were included) (http://www.emporis.com, 2010).

Given the ability of labor and capital to move to locations where the returns are greatest (Glaeser and Gotlieb, 2009), we would expect that this would lead to some degree of competition between these two leading cities. The literature on regional growth, however, has generally been silent on strategic interaction. Davis and Weinstein (2002) summarize the three main theories in regard to economic geography: increasing returns, random growth (Gibrat's Law), and locational fundamentals. None of these areas include any direct measures of interregional competition *per se*.[1]

More recently, regional science studies have investigated "the formation of policies designed to promote local economic development, often explicitly, but certainly implicitly, in competition with other territories" (Cheshire and Gordon, 1998, pp. 321–322). In this

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[1]Hollar (2011) investigates if central cities and suburbs are employment rivals or complements; he finds a complementary relationship.

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vein, governments specifically design tax policies, infrastructure investments, or land use regulations to lure business activity away from one region to another. But these types of direct government interventions generally did not exist in the nineteenth and early-twentieth centuries. Today these policies are often limited to specific projects, such as sports arenas (Siegfried and Zimbalist, 2000), tax abatements for specific corporations (Glaeser, 2001), or federally created industrial zones (Hanson and Rohlin, 2011).

Historically, skyscrapers have embodied two types of urban competition: regional competition for employment and industry growth, and competition among builders themselves to have a place within a "height hierarchy." Skyscrapers can be thought of as positional goods (Frank, 1985) due to psychological feelings of local pride and the desire of humans to engage in conspicuous consumption (or investment) to achieve social status (such as has been modeled in Helsley and Strange, 2008).

Competition, however, can lead to two possible outcomes. On one hand, if real estate developers build more space to lure businesses, it will have the effect of reducing the price of this space, and thus, in the vein of a Cournot model, the best-response function will have a negative slope. On the other hand, height in two cities might be strategic complements (Bulow, Geanakoplos, and Klemperer, 1985; Barr, 2012). If developers use their buildings to place themselves in a favorable position in the height market or urban hierarchy then builders will positively respond to the decisions of builders in the other city—thus creating a positively sloped reaction function. This work aims to test which effects might be present.

Clearly, the term "skyscraper" can have different meanings depending on the context. For example, a skyscraper can be defined based on its relative height compared with nearby buildings, or it can be defined based on technological considerations (i.e., built with a load-bearing steel skeleton and with an elevator). However, to simplify the analysis in this paper, a skyscraper here is defined based on two perspectives. The first is based on a fixed height. For New York, I use 90 m as the cutoff; for Chicago I use an 80 m cutoff.[2] From this definition, I create an annual time series of the number of skyscraper completions in each city. Presumably, competition can marginally influence whether a builder decides to build a "skyscraper" or not, and thus can affect the number of observed completions.

Second, I also look at the tallest building completed in each city each year since 1885. Since builders often use their skyscrapers for advertising (be it their corporations or their own egos), if there exists a competitive effect across cities, then presumably it would most likely appear at the extreme height level.

Based on time series data for New York and Chicago from 1885 to 2007, I find evidence for skyscraper interaction across cities. That is, New York skyscraper decisions have impacted Chicago's decisions and vice versa, controlling for other determinants of the skyline. First, I estimate reaction functions, and for all four variables (New York's completions count and maximum height, and Chicago's completions count and maximum height), I find evidence of strategic complementarity, as both cities show positive reactions with respect to the other city. In regard to zoning, I find that zoning regulations have reduced each city's own skyline. In addition, I find evidence that each city's regulations were met with increased building activity in the other city. These findings suggest the presence of strategic substitutability across cities.

The rest of this paper proceeds as follows. The next section reviews the relevant literature. Then Section 3 discusses the history of interactions between the two cities, as

[2]Eighty meters is used as a cutoff to increase the number of years with positive observations. Because of building height restrictions in Chicago there are several years without any "skyscraper" completions. However, regressions results using a 90 m cutoff are quite similar.

well as their respective policies on building height. Section 4 provides two simple models, which are then tested in Section 5. Finally, Section 6 offers some concluding remarks. Two Appendices provides additional information on the sources and nature of the data.

2. RELEVANT LITERATURE

To the best of my knowledge, no work within economics explores the determinants of building height in Chicago, nor is there any comparing New York to Chicago.[3] Regarding New York, early work includes that of Clark and Kingston (1930). Their objective was to estimate the economic height of a "typical" office tower in Manhattan as of 1929. They conclude that a 63-story building would provide the highest return using land prices, construction costs, and rent data.

More recently, a game-theoretic model of building height has been provided by Helsley and Strange (2008). They observe that within cities, the tallest building is often much taller than the surrounding buildings. This fact suggests that developers engage in height races, such as that observed between 40 Wall Street and the Chrysler building in 1929/30. Their model shows how strategic interaction can result in the construction of buildings that are economically "too tall," in the sense that the height contest can dissipate profits from construction.

These two works, however investigate skyscraper height for only one or two builders. They do not analyze the broader market for height. In this vein, Barr (2010, 2012) looks at the market for height in Manhattan over the period 1895–2004. Barr (2010) finds that there has been no upward trend in average heights over the last century; this provides evidence that, within Manhattan, ego-driven height does not appear to be a systematic component of the skyscraper market.

Barr (2012) looks at the determinants of building height, *at the building level*, in Manhattan over the twentieth century. The paper does find evidence of height competition, but that it is localized across both time and space, and only exists when the opportunity cost of competition is relatively low. Barr (2010, 2012) also investigates how height regulations have affected the New York skyline (with negative effects, in general). No work has looked at how zoning rules have affected height in Chicago.[4] There is also no work on how building height regulations in one city have either directly or indirectly affected height in other cities.

3. NEW YORK AND CHICAGO

Economic Interactions

With the completion of the Erie Canal in 1825, and the settling of Chicago in the 1830s, the two cities became linked economically, as capital, imports and settlers flowed West, while agricultural goods flowed East.[5] In 1871, Chicago's Great Fire spurred a series

[3]There is, of course, work on Chicago land values, land use, and the office market, all of which are related to skyscraper height. Land value work includes Hoyt (1933) and McMillen (1998). Studies on the Chicago office market include Mills (1992), Colwell, Munneke, and Trefzger (1998), and Abadie and Dermisi (2008).

[4]Papers such as Bertaud and Brueckner (2005) and Glaeser, Gyourko, and Saks (2005) investigate the effect of land use regulations on the construction and cost of housing. Geshkov and DeSalvo (2012) investigate how land use controls affect urban sprawl. McDonald and McMillen (1998) study how Chicago's 1923 ordinance affected land values.

[5]There does not appear to be any detailed accounts regarding the degree to which New York and Chicago engaged in trade. Works such as Haeger (1981) and Cronon (1991) describe the growth of Chicago

of real estate-related interactions. Since the fire swept away most of Chicago's downtown, new methods of fire-proof construction and tall building were implemented in the 1880s (Shultz and Simmons, 1959). This knowledge was then transferred to New York, where steel construction was introduced in 1888.

Architects, engineers, and builders who "cut their teeth" on Chicago's first generation of skyscrapers where employed in New York as well. This interaction has lead Zukowsky (1984) to write:

> Chicago and New York—these are often thought to be the two great superpowers of American architecture. Architects consider each city to have its own style, its own way of shaping its local environment, its own individualistic contributions to the history of architecture. Yet these contributions were not developed in isolation. Throughout the 19th and 20th centuries there has been, and still is, a considerable amount of competitive interactions between architects, contractors, and developers in both cities (p. 12).

The list of past and present interactions is long, but here I just list a few important examples. In the early period, arguably Chicago's most famous skyscraper architect, Louis Sullivan, designed one of his signature buildings in New York (Bayard Building, 1899). Builder and skyscraper pioneer, George Fuller, and his firm, built skyscrapers, such the Monadnock (1893) and the Rookery (1888) in Chicago, and the New York Times (1904) and Flatiron (1902) in New York City, which was also designed by one of Chicago's most famous architects, Daniel Burnham.

Competition between the two cities in this early period was keen. For example, the *Chicago Daily Tribune* (March 11, 1901) reports a typical case of interest:

> The newest thing in the racing field is the skyscraper. It involves Chicago and New York, and as usual Chicago is in the lead. A novel race of skyscrapers has been in progress for nearly a year at Cedar Street and Broadway, were two sixteen-story office buildings are going up on opposite corners . . . . The American Exchange National Bank Building is being erected on the northeast corner by a New York firm of builders, and on the northwest corner Chicago contractors are putting up the St. Lawrence Building . . . . The Chicago firm celebrated its triumph today by hanging out a sign announcing that its building will be ready for occupancy in May. The New York firm admits that it can only finish in time for the autumn renting (p. 2).

In the 1920s, architect Raymond Hood, who resided in New York, designed both the Chicago Tribune Tower (1924) and the New York Daily News Building (1929). After World War II, German-born architect Ludwig Mies van der Rohe, head of the architecture department at Chicago's Illinois Institute of Technology, designed one of New York's most famous modernist buildings, the Seagram Building (1958). The architecture firm Skidmore, Owings and Merrill (SOM), founded in Chicago in 1936, has designed many buildings in the two cities, including the Sears Tower (1974) and the John Hancock Tower (1969) in Chicago, and the Lever House (1952) and One World Wide Plaza (1989) in New York. Finally, New York-based builder Donald Trump, who has built many skyscrapers in New York, in 2009 completed the 92 story Trump International Hotel and Tower (designed by SOM) in Chicago.

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and the Old Northwest. To some degree they chronicle the extent to which eastern capitalists and entrepreneurs invested in the region; but they do not provide specific measurements of the urban-level current and capital accounts between the two cities.

Over the years, however, Chicago has developed a reputation for suffering from "Second City Syndrome." That has prompted Chicago newspaper reporter Don Hayner (2000) to write:

> Chicago always wanted to show the world who was boss. And in case you haven't heard, it ain't New York. No matter what it achieved, Chicago saw itself as the underdog with the "second city" syndrome. But its insecurity gave the city its power. Chicago wanted to be better than the best, but never felt like it was. So it kept challenging New York and L.A. like a kid picking a fight with the toughest punk on the corner" (p. 212).

This quote suggests two things about the competition hypothesis: (1) Chicago positively responds to New York's skyscraper decisions, and (2) if New York also responds positively to Chicago, then Chicago's coefficients are larger than New York's, since it needs to out-do New York to compensate for its feelings of low esteem. This paper investigates this Second City Hypothesis in the empirical section below.

New York's Zoning and Policies

New York's first "skyscraper," the Tower Building (11 floors), was completed in 1889, about four years after Chicago's first, the Home Insurance Building. After that, steel-skeleton construction in New York became commonplace. The first generation of skyscrapers were not subject to any height or bulk regulations, and 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 comprehensive zoning rules that stated height and use regulations for all lots in the city. In 1961, New York City implemented an updated zoning law.

Unlike Chicago, New York has never directly capped the heights of buildings. Rather the 1916 code created setback requirements. That is, 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.[6]

In the 1970s and 1980s, New York implemented three additional programs that were designed to promote high-rise construction. From 1982 to 1988, a special midtown zoning district was created to encourage development on the west side of midtown by allowing FAR bonuses of up to 20 percent. 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 Board 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 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 they 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 on to the buyers. The program was curtailed for most of Manhattan in 1985.

[6]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 10 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.

TABLE 1: Building Height Regulations in Chicago and New York

Year Implemented	Chicago	New York
1893	130 ft (39.6 m) limit	
1902	260 ft (79.2 m) limit	
1911	200 ft (61.0 m) limit	
1916		Setback multiple
1920	260 ft limit + 400 ft for tower (total 183 m)	
1923	264 ft + tower, with area and volume limits	
1942	144 × lot size (FAR≈12)	
1957	FAR limits + bonus	
1961		FAR limits + bonus

Chicago's Height Limitations

Between 1893 and 1923, Chicago placed direct limits on the height of buildings. Table 1 summarizes the building height regulations in New York and Chicago. In 1893, Chicago imposed a 130 ft limit on the height of buildings (about 10 stories or 39.5 m).[7] Several more towers were completed after 1893, since the permits for these building were issued prior to implementation. In 1902, the building height limit was doubled to 260 ft; but only nine years later in 1911, the maximum height was reduced to 200 ft.[8]

In 1920, a new approach was taken. The height limit was raised again to 260 ft, but builders were also allowed to construct ornamental towers that could rise to 400 ft (though these towers could not be occupied).[9] Then in 1923, the height limit was raised to 264 ft and habitable towers were permitted. Though there was no limit on tower height, the area of the tower had to be less than 25 percent of the plot area and less than one-sixth of the volume of the main building. These rules were in effect until 1942. In that year a more flexible approach to height was implemented. For much of downtown Chicago, the maximum building volume was capped at the area of the plot times 144 ft. This gave builders the equivalent of an FAR of roughly 12. Given the Great Depression and World War II virtually no skyscrapers were built during this zoning period.

Finally, starting in 1957 the current approach was implemented. Builders were given FAR caps (a similar set of rules was implemented in New York in 1961). In downtown Chicago, builders had a FAR of 16; FAR bonuses were given if builders provided open space around the building. As in New York, these regulations promoted the boxy towers that are common today.[10]

[7]On one hand, height restrictions can be based on a "distaste" for height or to curb negative externalities, and as such, the city can impose height restrictions to improve city-wide utility, at the expense of real estate developers. On the other hand, the height restrictions might simply have been a legal embodiment of what the economic climate would have generated anyway. Builders and landlords might have lobbied for height restrictions to curb ego-based builders, who, presumably, did not care about the effects of nonpecuniary motivated height on real estate prices. If height restrictions are binding it would suggest evidence for the former hypothesis, rather than the latter.

[8]Evidently, the economic interactions between the two cities did not preclude tongue-and-cheek comments from the *New York Times*. On March 2, 1902, the newspaper reported, "That sky-scraper limit [in Chicago] has now positively been fixed at 260 ft, until someone comes along who wants to a build a taller one" (p. 10).

[9]The fact that 400 ft uninhabitable towers were allowed in Chicago strongly suggests a demand for buildings that could be used for advertising or strategic purposes.

[10]For a detailed discussion of the history of zoning in Chicago, see Schwieterman and Caspall (2006). See Weiss (1992) for a history of building height regulation in New York and other cities.

In regard to zoning regulations, the questions of interest here are: (a) is there evidence that height restrictions were binding in each city, and (b) to what extent did restrictions in one city affect skyscraper construction in the other? Shultz and Simmons (1959) argue that height limitations in Chicago where helpful to New York. They write that during the fixed height limitations period, "New York could and did build office buildings to house the great expansion of business. Some of this business wanted to come to Chicago and would have if it could have been accommodated there" (pp. 286–287).

4. MODELS OF SKYSCRAPER INTERACTIONS

Here, I present two simple models of skyline competition, in order to generate some testable hypotheses.[11] The first model assumes that skyscrapers are inputs used for the production of a tradeable good. The second model assumes that skyscrapers are used to produce nontradeable, local goods and services, which can include civic pride, aesthetic enjoyment, or advertising, as well as space for local firms.

A Strategic Substitutes Model

To begin, assume that two cities produce the same tradeable good, Q, such as financial, legal, marketing or "headquartering" services, which, because of low communication costs (such as telephone, Internet, or mail) can be produced in either location and distributed to customers throughout the national market.[12] In this case, we can model two cities as being engaged in Cournot competition for that output.

For simplicity, assume that city output is given by $Q_i = K_i^{\delta}$, $i = 1, 2$, where $0 < \delta < 1$.[13] K is a measure of skyscraper capital. Assuming plots of land are fixed at one unit, K can have two possible interpretations, which I investigate below: either as the total number of skyscrapers, or as a measure of their heights. For now, K is a general measure of skyscraper capital, and additions to the capital stock are either the number of new skyscrapers completions or a measure of their heights.[14]

Furthermore, assume a linear demand function for the urban good, given by: $P = \alpha - (Q_1 + Q_2)$, with $\alpha > 0$, $P \geq 0$. Without loss of generality, focus on City 1, which has a city product given by

$$\pi_1^{tr} = \left[\alpha - \left(K_1^{\delta} + K_2^{\delta}\right)\right] K_1 - C(K_1, c) - t_1 K_1, \quad (1)$$

where π_1^{tr} is the net income from the tradeable good. $C(K_1, c)$ is the cost of creating and maintaining the capital stock, with $C_{K_1} > 0$, $C_{K_1K_1} > 0$; $c > 0$ is a cost parameter, with $C_c > 0$. Since the focus on this paper is on new construction (i.e., additions to the capital stock), and to keep the model simple, I assume that height regulations represent an implicit tax on capital, $t_1 K_1$.

[11] I leave a more sophisticated, general-equilibrium model for future work.

[12] As Strauss-Kahn and Vives (2009) show, the New York and Chicago regions are leading centers for headquarters. As of 1996, New York and Chicago ranked first and third in the nation in terms of the number of headquarters, respectively. In addition, their work shows that headquarters relocation is a significant phenomena.

[13] Two notes about this production function. Since the variable of interest is skyscrapers, for simplicity, I drop labor from the production function. Second, I do not assume any agglomeration economies. I leave for future work estimates of how skyscrapers may increase city productivity due to knowledge spillovers and lower communication costs.

[14] There are, of course, other measures, such as total building space or average heights. For the sake of brevity, these other variables are not explored in this paper.

Let K_1^* be the profit-maximizing capital stock that solves the first-order condition

$$\alpha - (1+\delta)K_1^{\delta} - K_2^{\delta} - C_{K_1} - t_1 = 0.$$

The best-response function has a negative slope, with respect to K_2, since $\partial K_1^*/\partial K_2 = -\pi^{tr}_{K_1K_2}/\pi^{tr}_{K_1K_1} < 0$. The two goods are strategic substitutes because $\pi^{tr}_{K_1K_2} = -\delta K_2^{\delta-1} < 0$. Finally, we have $\partial K_1^*/\partial\alpha > 0$, $\partial K_1^*/\partial c < 0$, and $\partial K_1^*/\partial t_1 < 0$.

Given the relatively long lags between project announcements and completions, and the fact that information about projects is widely available during construction, this paper focuses on estimating reaction functions.[15] Standard Cournot models assume decisions are made without knowledge of a rival's decision. However, in regard to skyscrapers, this assumption is not fully valid. While builders can keep their final, exact heights a secret, generally speaking, a large amount of information is available about each project (given media coverage, building permit information, developer business associations, and real estate brokers who market the building). Developers in one city would use this information about the other when planning their buildings, and if competition exists we would expect one city's skyscraper outcomes to influence the other. The specific timing of these interactions is explored in the empirical section below.

In summary, based on the model, if skyscrapers represent strategic substitutes, we would expect to see that increases in skyscrapers in one city lead to decreases in height and/or completions in the other. In addition, shifts in the demand for the product will increase height and/or completions; increases in construction and maintenance costs will reduce height and/or completions. Finally, zoning regulations are predicted to reduce skyscraper completions, because they act as a *de facto* tax on supply.

A Model of Local Demand and Urban Competition

Skyscrapers, however, are not just inputs for the production of a tradeable good; they are also local goods unto themselves. For example, they can be used for advertising, views, aesthetic appreciation, to enhance feelings of local pride, and as a form of "conspicuous production," in the vein of large historical public works with minimal productive uses, such as the Eiffel Tower or the Egyptian or Aztec pyramids.[16]

Thus, we can imagine two aspects of skyscrapers (putting aside the Cournot model for now): the quantity demanded for local urban output and that part due to "skyline competition." First assume that there's a local demand for skyscrapers in City 1 given by $P(K_1) = \alpha - K_1$. Furthermore, the value of K_1 is determined, in part, relative to K_2; as K_2 increases it lowers the value of the local good by reducing tourism, advertising revenues, or local pride.

Thus, for City 1 the value of the nontraded good is given by

$$\pi_1^{nt} = (\alpha - K_1)K_1 + \theta\left(1 - \frac{K_2}{K_1}\right) - C(K_1, c) - t_1K_1, \tag{2}$$

where the term $R_1 \equiv \theta(1 - \frac{K_2}{K_1})$ represents how the relative size of the two skylines affects City 1, with $\theta > 0$. If $K_1 > K_2$, then $R_1 > 0$.[17] The first-order condition for City 1 gives a

[15]Note that equilibria exist for the models presented in this paper.

[16]When F.W. Woolworth announced the record breaking skyscraper he planned to build, he told a *New York Times* reporter, "I do not want a mere building, I want something that will be an ornament to the city" (*New York Times*, Nov. 13, 1910, p. RE1).

[17]Assuming that a city has a demand for skyscrapers as both capital for a traded good (K^{tr}) and as local "consumption" good (K^{nt}), then, there would be positive cost benefits when both types of capital are built, i.e., $C_{K^{tr}K^{nt}} < 0$. Without loss of generality, this cost benefit is ignored in this paper.

K_1^* that solves

$$\alpha - 2K_1 + \theta \frac{K_2}{K_1^2} - C_{K_1} - t_1 = 0.$$

In this case, the reaction function is positive: $\partial K_1^*/\partial K_2 = -\pi_{K_1K_2}^{nt}/\pi_{K_1K_1}^{nt} > 0$. Thus when there is an increase in City 2's capital stock, City 1's best response is to increase its capital stock. The two cities find that skyscrapers in this case are strategic complements since $\pi_{K_1K_2}^{nt} = \theta/K_1^2 > 0$; also note that $\pi_{K_1K_1}^{nt} < 0$. As above, $\partial K_1^*/\partial\alpha > 0$, $\partial K_1^*/\partial c < 0$, and $\partial K_1^*/\partial t_1 < 0$.

From this section we have the following hypotheses. If height is a strategic complement, there will be a positive reaction function, i.e., increases in skyscrapers in one city will drive increases in the other. Increases in local demand will positively effect skyscraper construction; increases in costs or the introduction of height regulations will reduce construction.

If we look at the combined effect of $\pi_{K_1K_2}$ from Equations (1) and (2), we have

$$sign[\pi_{K_1K_2}] = sign\left[\frac{\theta}{K_1^2} - \frac{\gamma\delta}{K_2^{1-\gamma}}\right].$$

The net effect can be positive or negative, depending on the values of K_1, K_2 and the parameters. Finally, the effect of zoning regulations on the other city can be positive or negative. If City 1 imposes a zoning "tax," t_1, then builders will respond by lowering their height, i.e., $\partial K_1^*/\partial t_1 < 0$. The effect on City 2 will depend on its own reaction function, because City 2 will then observe a reduction in heights in City 1 (with some lag) due to the regulations, and whether this is met with increased or decrease height depends on the sign of $\partial K_2^*/\partial K_1$.

5. TESTS FOR STRATEGIC INTERACTION

The purpose of this section is to test the hypotheses regarding strategic interaction in the two cities, as provided by the different models. I focus on two variables, the number of skyscraper completions in each city, each year, $\ln(1 + count)_{it}$, $i = \{New\ York, Chicago\}$, $t = \{1885, \ldots, 2007\}$, and the height of the tallest building completed in each city, each year, max_{it}.[18] The first variable tests for skyscraper developer competition; the second variable tests for direct height competition. The general estimation strategy is to include one or more variables from one city on the right-hand side of an equation with the other city's dependent variable. I have collected data for four types of variables: (1) the factors that determine the demand for new space (such as employment and population); (2) the factors that determine the supply of skyscrapers, such as costs of construction, supply of investment capital, and total completed stock; (3) government policy variables; and (4) strategic interaction variables.

The Data

Table 2 gives the descriptive statistics of the data set used in this paper. Appendix A gives the details about the sources and the preparation. As the table demonstrates, I have included a substantial number of supply and demand variables for each city. This is

[18]Levels rather than logs of the maximum is preferred for two reasons: first is that it appears to provide a better fit, and second it avoids a discontinuity problem that would arise when taking logs when maximum height is zero.

TABLE 2: Descriptive Statistics

Variable	Mean	St. Dev.	Min.	Max.	No. Obs.
New York Skyscrapers					
Maximum Height (m)	156.5	76.8	18.0	417.0	123
Completions	6.41	7.55	0.0	37.0	123
Net Total Completions	269.9	239.6	1.0	773.0	118
Avg. Plot Size (sq. ft)	43,820	36,564	5,198	241,478	98
Plot Size of Max. (sq. ft)	59,743	105,480	1,487	681,600	123
Chicago Skyscrapers					
Maximum Height (m)	113.6	88.6	0.00	442.3	123
Completions	3.67	4.52	0.00	16.0	123
Net Total Completions	134.0	136.1	1.00	442.0	124
Avg. Plot Size (sq. ft)	41,244	22,369	9000	143,828	73
Plot Size of Max. (sq. ft)	45,719	44,601	4080	282,492	112
U.S. Variables					
ln(RGDP) Detrended	0.00	0.12	−0.47	0.20	123
FIRE Emp./Emp. (%)	4.52	1.42	1.94	6.57	118
Real Material Cost Index	1.22	0.25	0.82	1.61	124
%ΔU.S. Real Estate Loans	8.22	8.43	−19.1	42.2	117
%ΔS&P Index	6.37	18.05	−48.50	49.90	123
Real Interest Rates (%)	2.25	4.81	−14.76	19.57	123
ln(Real Estate Construction) Detrended	0.00	0.510	−2.34	0.725	125
Max. U.S. Height excl. NYC & Chi. (m)	136.1	75.03	0.00	312	123
New York Economic Variables					
Regional Population (M)	11.10	4.09	3.09	16.00	123
NYSE Volume (B)	36.7	100.0	0.033	532.0	120
Zoning Dummy (1916–1960)	0.36				124
Zoning Dummy (1961–2007)	0.38				124
Zoning Bonus Dummy (1982–1988)	0.06				124
Tax Abatements Dummy (1971–1985)	0.12				124
ICIP Dummy (1977–1992)	0.13				124
Chicago Economic Variables					
Regional Population (M)	5.19	2.33	1.00	8.59	124
CSE Volume (B)	1.79	5.50	0.0002	30.1	116
Zoning Height Limits Dummy (1893–1941)	0.40				123
Zoning FAR Limits Dummy (1941–2007)	0.54				123

done for two reasons. First, since there is little work in this area, it helps to understand which are the important variables that drive skyscraper construction across cities; second, and, more importantly, it is necessary to include many control variables, so that tests for interaction provide evidence for causality.

To estimate the demand for skyscrapers for tradeable or nontradeable goods, I have included the following variables. First is the detrended log of real Gross Domestic Product (GDP). A second demand variable is the percent of U.S. employment in the Finance, Insurance and Real Estate (FIRE) sectors. Another demand variable is the annual metropolitan area population of each city. We would expect to see positive coefficients for these variables.

I also include two measures of stock market activity which presumably affect the demand for skyscrapers. First is the percent change in the Standard and Poor's (S&P) Stock Index. When the value of the S&P is increasing, it means firms are more profitable and they are more likely to be increasing both their demand for office space, and potentially using some of those profits to engage in height advertising. As a second measure, I include the log of average daily volume of the New York and Chicago stock exchanges, respectively. In theory, the more trading activity, the more profits will go to finance-based firms, who will then demand more office space and height. For all of the above-mentioned variables, we would expect to see positive coefficients.

In terms of supply side variables, I include the percent change in the dollar value of real estate loans made each year by commercial banks. This is a measure of the supply of construction capital. I also include the real interest rate as a measure of the cost of capital. To measure construction costs, I include an index of the real value of construction materials. Finally, for each city I also include the net cumulative number of skyscraper completions in each city as a measure of the total stock of skyscrapers. For interest rates, materials cost and cumulative completions, we would expect to see negative coefficients, but positive ones for growth in real estate loans.

In regard to height regulations, for each city I include dummy variables for the years that various zoning regimes and incentive programs were in place, as discussed in Section 3. For New York, I include two zoning dummy variables: one for the period of 1916–1960, and one for the period 1961–2007. For Chicago, I created two dummy variables in order to simplify the analysis and increase the degrees of freedom. First, I created a dummy variable from 1893 to 1941. During this period, Chicago had height caps on buildings. While the caps changed over the period, I include only one dummy variable to capture their average effect. A second dummy variable was included for the years 1942–2007, when FAR zoning rules were in effect.[19] For zoning variables, we would expect negative signs. For New York's building incentive programs, we would expect to see positive signs.

I also include measures of the plot sizes. Plot size is an important component of the economics of skyscrapers since it affects both the marginal costs and benefits to height. The expectation is that larger plot sizes make taller buildings more economical, and would thus increase the number of observed completions. Because plot sizes are important, excluding them may introduce omitted variable bias. However, the variable might be endogenous if builders who have a particular desire to build tall seek out extra large plots. In the end, I have included this variable, as the available evidence suggests that plot size is exogenous. First, Barr (2012) does not find evidence of plot size endogeneity for Manhattan. Second, as discussed below, plot sizes are considered as possible instruments, and in all cases, I cannot reject the null hypotheses for the test of overidentifying restrictions. In other words, when plot sizes are included in the first stage of a two-stage least-squares regression, all the instruments are shown to be exogenous (test results are given in Appendix B). The determinants of plot size are often out of the control of builders (due to holdouts, unusual plot shapes, the placement of roads and railroads near some blocks) and thus there is no strong *a priori* reason to assume that endogeneity is a major problem in this regard.[20]

To the extent possible, I have aimed to collect city- or regional-specific variables. But for some of the demand and supply variables, such local measures are not available over

[19]Increasing the number of Chicago zoning dummy variables does not generally change the results. The more dummy variables included the less is the statistical significance of the coefficients

[20]Note that the estimates of the strategic interaction variables do not significantly change when plot sizes are omitted; however, omission of plot sizes appears to inflate the effects of zoning (results are available upon request).

the entire sample period. While measures of office employment and construction costs do exist they tend to be available for the post-World War II period or may be available for some years for one city but not another. For this reason, I have only included variables that I have been able to obtain for at least 100 years, which can be local or national in scope.

Finally, for the majority of the variables, the right-hand side variables are lagged two years to account for the lag time in construction. In some cases, lags of three years provided a better fit of the data; this was the case for finance-related variables, since presumably financing must first be arranged before construction can begin.

Estimation Issues

In order to properly measure the determinants of skyscrapers in each city, several estimation issues need to be considered. First is the estimation procedure; second are issues relating to the standard errors (i.e., heteroskedasticity and serial correlation); third are issues regarding the strategic interaction variables; and finally, there is the issue of endogeneity for these interaction variables.

First, I have explored three estimation methods: ordinary least squares, two-stage least squares, and seemingly unrelated regressions (SURE). The tables in the next section present results from all three. The preferred estimation method is to include all four dependent variables,

$$y_t = \{\ln(1+count)_{NYC,t}, \ln(1+count)_{Chi,t}, max_{NYC,t}, max_{Chi,t}\},$$

in a SURE because the error terms appear to be correlated across equations.[21] The SU regressions were estimated using maximum likelihood, and robust standard errors were calculated.[22]

Regarding the standard errors, all equations where tested for heteroskedasticity and serial correlation. Appendix B gives the results for these tests. In general, the bigger problem is that of heteroskedasticity. For a few equations, there is (weak) evidence for serial correlation based on the Breusch–Godfrey LM test for autocorrelation. In these cases other tests were performed (described in the Appendix), and the overall conclusion is that given the specifications, serial correlation of the error terms in not an issue.

In regard to the choices of variables used to test for strategic interaction, the preferred specification for each equation is to include one (or more) lags of the other city's dependent variable on the right-hand side. That is, the preferred model for each city is a reaction function given by

$$y_{it} = \mathbf{x}_{it-n}\beta + \alpha_1 y_{it-1} + \alpha_2 y_{-i,t-n} + \mu_{it}, \tag{3}$$

where y_{it} is the dependent variable—$\ln(1+count)$ or max—in city i in year t, $\mathbf{x}_{it-n}$, $n = 2$ or 3, is a vector of control variables (which are lagged to account for the time to build), y_{it-1} is the lagged dependent variable for city i, y_{-it-n}, $n = 1$ or 2, is the other city's skyscraper variable, which is the same type as y_{it}.[23,24] μ_{it} is the error term. Using lagged variables

[21]The χ^2 statistic for the null hypothesis of no correlation across residual is 43.4, with a P-value of 0.00.

[22]The SUREs were run in Stata 10.1 using the "mysureg" command (Gould, Pitblado, and Sribney, 2006).

[23]For simplicity and the sake of consistency, for the strategic variables, I have included on the right-hand side the other city's dependent variable (e.g., for New York City's count equation, I include Chicago's count). I leave for future work exploration of other strategic variables such as average or total heights.

[24]With a slight abuse of notation, n is used to denote a lag, however, n will be different across variables.

precludes possible endogeneity for these variables when there is no serial correlation in the error term.

For one dependent variable, $\ln(1 + count)_{NYC,t}$, there was no serial correlation when Chicago variables were excluded, but there was serial correlation when $\ln(1 + count)_{Chi,t-1}$ was included on the right-hand side. However, when $\ln(1 + count)_{Chi,t-2}$ was also included, the serial correlation was no longer present. So for the New York count equation, two lags of Chicago's count were included. In the regression below, I use either $n = 1$ or 2 depending on the significance of the coefficient. *A priori* it's not clear if lags of one or two years is better because of the long lags involved with high-rise construction.

All equations included a lagged dependent variable (for its own city) as a way to control for possible lagged effects in the building decisions in that city. Since the time to completion can vary several years, the lagged dependent variable is a way to control for this and other omitted variables. This is important because there may be similar economic variables driving the skylines of the two cities and if we are to investigate intercity effects, the inclusion of a lagged dependent variable would more likely control for unmeasured city-specific effects that might confound intercity effects. In addition, inclusion of a lagged dependent variable can eliminate or reduce serial correlation of the residuals.

Finally, I also ran two-stage least squares using contemporary measures of strategic interaction. For instruments, I used each city's lagged population measure and plot sizes, on the assumption that these variables are correlated with skyscraper building in one city, but not the other. The results of the instrumental variables tests are given below in Appendix B. The conclusions of the tests were as follows. All instruments used were shown to be exogenous via the test for the overidentifying restrictions; all instruments were strong, with all but one F-statistic above 10.00. The endogeneity test did show evidence that the count variables were endogenous (but not the maximum height variables). Finally, when two-stage least squares was run, the endogenous variables were all statistically insignificant, but most had positive coefficients.

Reaction Function Estimates

The results are presented in four tables. Tables 3 and 4 are for New York and Chicago completions, respectively; Tables 5 and 6 are for New York and Chicago's maximum height, respectively. In each table, Equation (1) is the "basic" equation, with no strategic interaction variables. Equation (2) is from a two-stage least squares that includes the other city's contemporaneous strategic variable. For example, in Table 3, the dependent variable is New York's count, and Equation (2) includes on the right-hand side Chicago's count, which was first estimated using instrumental variables. Equation (3) in each table is estimated via ordinary least squares (OLS) and includes on the right-hand side the lag of the other city's variable. Finally, Equation (4) presents the results of the SURE (i.e., each table presents one of the four equations estimated via SURE).

For New York counts, Table 3, we see that the variables all have the expected signs. For New York City, detrended GDP, however, is not a statistically significant determinant of skyline growth; while employment in finance, insurance, and real estate is positive; it is inelastic, but close to unitary elastic in Equation (4). The count is elastic with respect to the metropolitan area population. Stock market activity (trading volume and market returns) are positively related to the count, which supports the hypothesis that growth in the finance industry translates to greater demand for skyscrapers.

With respect to supply variables, the coefficients have the expected signs. The count is negative and elastic with respect to the total stock and materials costs; it is positive

TABLE 3: Regression Results for ln(1 + *Count*) for New York City

	(1) OLS	(2) 2SLS	(3) OLS	(4) SURE
ln(RGDP) Detrended$_{t-2}$	0.205 (0.34)	0.382 (0.76)	0.245 (0.52)	0.506 (1.22)
ln(FIRE)$_{t-2}$	0.808 (1.82)*	0.883 (2.60)***	0.815 (2.54)**	0.961 (3.15)***
ln(Total Stock)$_{t-2}$	−1.65 (4.57)***	−1.33 (2.99)***	−1.09 (3.04)***	−1.00 (3.51)***
ln(Materials Cost)$_{t-2}$	−3.02 (5.13)***	−2.66 (4.05)***	−1.54 (2.78)***	−1.65 (3.17)***
ln(Stock Volume)$_{t-2}$	0.193 (3.38)***	0.160 (2.71)***	0.153 (2.88)***	0.139 (3.04)***
ln(Metro. Pop.)$_{t-2}$	7.09 (4.65)***	5.76 (3.05)***	4.37 (2.82)***	4.13 (3.33)***
%ΔRE Loans$_{t-3}$	0.017 (2.74)***	0.014 (2.90)***	0.012 (2.38)**	0.014 (2.89)***
%ΔS&P Index$_{t-3}$	0.007 (2.84)***	0.007 (3.52)***	0.006 (2.61)***	0.006 (3.08)***
Interest Rate$_{t-3}$	−0.005 (0.48)	−0.008 (0.89)	−0.008 (0.83)	−0.005 (0.59)
NYC Zoning Bonus$_{t-2}$	0.415 (1.95)*	0.404 (2.42)**	0.455 (2.41)**	0.439 (3.36)***
NYC Tax Abatement$_{t-2}$	0.404 (2.60)**	0.384 (3.05)***	0.354 (2.55)**	0.387 (3.48)***
NYC ICIP$_{t-2}$	0.397 (1.88)*	0.305 (1.39)	0.170 (0.87)	0.121 (0.86)
NYC Zoning 1916 Dummy$_{t-2}$	−0.102 (0.35)	−0.146 (0.63)	−0.052 (0.23)	−0.132 (0.61)
NYC Zoning 1961 Dummy$_{t-2}$	−0.338 (0.82)	−0.425 (1.25)	−0.555 (1.65)	−0.636 (1.98)**
ln(1+Chicago Count)$_t$		0.123 (1.09)		
ln(1+Chicago Count)$_{t-1}$			0.240 (3.51)***	0.247 (4.57)***
ln(1+Chicago Count)$_{t-2}$			0.178 (2.46)**	0.100 (1.53)
ln(1+NYC Count)$_{t-1}$	0.243 (3.56)***	0.207 (2.54)**	0.074 (0.94)	0.113 (1.77)*
ln(Plot Size)	0.085 (6.86)***	0.088 (8.36)***	0.082 (7.99)***	0.080 (8.38)***
Constant	−109.8 (4.71)***	−89.5 (3.11)***	−68.1 (2.81)***	−64.6 (3.42)***
Observations	114	114	114	113
R^2	0.86	0.88	0.89	0.89

Notes: Equations (1) and (2) give *t*- and *z*-statistics, respectively; Equations (3) and (4) give robust *t*- and *z*-statistics, respectively. ***Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and *Stat. sig. at 90 percent level.

with respect to growth in real estate loans. The interest rate has a negative coefficient, but is not statistically significant.

Looking at Table 4, we can see similar results in terms of the coefficient signs. The demand variables are positive, but only metropolitan population shows consistent statistical significance, and an elasticity greater than one. The supply-related variables also show the expected signs, but, unlike New York, the materials and total stock coefficients are inelastic. The reasons for the differences in coefficient estimates between the two cities is left for future work.

In regard to maximum height, the demand-related variables in Tables 5 and 6 show the expected signs. If we assume that one floor is about 3.5 m, then we would predict for example, that a 10 percent increase in FIRE employment in New York adds about 1–1.5 additional floors to the tallest building completed each year; for Chicago, the prediction is about two floors, on average, for each 10 percent increase in FIRE employment. Maximum height rises with GDP. For example, in New York, a 10 percent increase of GDP above

TABLE 4: Regression Results for ln(1 + *Count*) for Chicago

	(1) OLS	(2) 2SLS	(3) OLS	(4) SURE
ln(RGDP) Detrended$_{t-2}$	1.29 (2.34)**	1.53 (2.82)***	1.11 (2.16)**	0.704 (1.35)
ln(FIRE)$_{t-2}$	0.673 (2.09)**	0.854 (2.58)***	0.575 (1.78)*	0.334 (1.05)
ln(Total Stock)$_{t-2}$	−0.428 (2.42)**	−0.424 (2.40)**	−0.439 (2.50)**	−0.547 (3.54)***
ln(Material Cost)$_{t-2}$	−0.415 (0.80)	−0.359 (0.73)	−0.471 (0.93)	−0.723 (1.43)
ln(Stock Volume)$_{t-2}$	0.000 (0.01)	−0.006 (0.23)	0.004 (0.14)	0.020 (0.83)
ln(Metro. Pop.)$_{t-2}$	1.69 (2.52)**	1.65 (2.48)**	1.70 (2.51)**	2.10 (3.29)***
%ΔRE Loans$_{t-3}$	0.006 (1.12)	0.008 (1.41)	0.006 (1.14)	0.009 (1.92)*
%ΔS&P Index$_{t-3}$	0.001 (0.25)	0.001 (0.55)	0.001 (0.23)	0.000 (0.15)
Interest Rate$_{t-3}$	0.008 (0.97)	0.010 (1.17)	0.006 (0.84)	0.008 (1.13)
Zoning Height Restrictions$_{t-2}$	−0.171 (1.25)	−0.072 (0.49)	−0.221 (1.46)	−0.412 (2.35)**
Zoning FAR Limits$_{t-2}$	−0.530 (2.34)**	−0.491 (2.22)**	−0.526 (2.28)**	−0.586 (2.24)**
ln(1+NYC Count)$_t$		−0.099 (1.22)		
ln(1+NYC Count)$_{t-1}$			0.071 (0.79)	0.197 (2.51)**
ln(1+ Chi Count)$_{t-1}$	0.339 (5.68)***	0.387 (5.26)***	0.307 (4.95)***	0.262 (4.23)***
ln(Plot Size)	0.098 (8.16)***	0.100 (8.08)***	0.095 (6.78)***	0.073 (6.92)***
Constant	−24.7 (2.60)**	−24.5 (2.58)***	−24.8 (2.59)**	−30.2 (1.16)
Observations	113	113	113	113
R^2	0.87	0.87	0.88	0.88

Notes: Robust *t*-statistics below estimates given in Equations (1) and (3); robust *z*-statistics given in Equations (2) and (4). *** Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and * Stat. sig. at 90 percent level.

trend is associated with an increase in height of about 6.2–7.5 m (about two floors); while for Chicago, the increase is about 19.7–22.2 m (around six floors). We see that New York is more sensitive to population increases, with height rising about 37–42 m (about 10–11 floors) with a 10 percent rise in population; for Chicago the estimates are between 6.6 and 11.2 m (about two to three floors). For equity trading volumes, we see a positive effect for New York, and no statistically significant effect for Chicago.

For the supply-related variables we also see the expected signs for total stock and materials costs, though the coefficients are not statistically significant for Chicago. For interest rates, unexpectedly, we see a positive effect for Chicago and no effect for New York.[25]

In general the zoning variables have the correct signs, however statistical significance varies. Table 7 shows the results of χ^2-tests for the joint significance of the zoning coefficients (which are based on the coefficients from the SU regressions, Equation (4) in each table). The table does provide evidence that height restrictions reduced the number of completions, but had less effect on the maximum annual height.

[25] Across equations, the interest rate is either positive or not statistically significant. Maccini, Moore, and Schaller (2004) show that interest rate regime switches need to be included to better capture the effect of interest rates on capital investments. I leave investigating this for skyscrapers for future work.

TABLE 5: Regression Results for New York's Maximum Height (meters)

	(1) OLS	(2) 2SLS	(3) OLS	(4) SURE
ln(RGDP) Detrended$_{t-2}$	62.2 (0.88)	64.6 (0.99)	62.8 (0.93)	75.2 (1.22)
ln(FIRE)$_{t-2}$	50.4 (1.34)	50.7 (1.46)	42.3 (1.12)	36.9 (1.11)
ln(Total Stock)$_{t-2}$	−99.5 (2.66)***	−87.0 (1.81)*	−90.9 (2.55)**	−79.4 (2.39)**
ln(Materials Costs)$_{t-2}$	−200.9 (3.12)***	−192.8 (3.10)***	−186.0 (2.88)***	−171.9 (2.99)***
ln(Stock Volume)$_{t-2}$	16.4 (3.02)***	14.9 (2.36)**	15.8 (2.96)***	13.4 (2.82)***
ln(Metro. Pop)$_{t-2}$	446.7 (2.77)***	403.2 (2.10)**	412.8 (2.68)**	366.6 (2.56)**
%ΔRE Loans$_{t-3}$	0.776 (1.41)	0.527 (0.70)	0.552 (0.96)	0.522 (0.99)
%ΔS&P Index$_{t-3}$	0.046 (0.12)	0.042 (0.11)	−0.055 (0.14)	−0.059 (0.17)
Interest Rate$_{t-3}$	0.138 (0.11)	−0.136 (0.13)	−0.141 (0.11)	0.236 (0.20)
NYC Zoning Bonus$_{t-2}$	7.13 (0.57)	1.98 (0.11)	11.7 (0.94)	17.4 (1.42)
NYC Tax Abatement$_{t-2}$	12.2 (0.70)	7.25 (0.36)	7.23 (0.41)	11.1 (0.72)
NYC ICIP$_{t-2}$	35.3 (1.53)	35.6 (1.69)*	31.0 (1.39)	25.2 (1.25)
NYC Zoning 1916 Dummy$_{t-2}$	−34.0 (1.44)	−39.7 (1.91)*	−33.5 (1.42)	−25.6 (1.23)
NYC Zoning 1961 Dummy$_{t-2}$	−72.7 (1.98)**	−82.6 (2.23)**	−78.8 (2.08)**	−68.4 (1.99)**
Chi Max. Height$_t$		0.116 (0.50)		
Chi Max. Height$_{t-2}$			0.133 (1.79)*	0.120 (1.61)
NYC Max. Height$_{t-1}$	0.319 (3.25)***	0.281 (2.58)***	0.278 (2.72)***	0.318 (3.14)***
ln(Plot Size)	24.1 (4.08)***	23.7 (4.42)***	25.3 (4.39)***	23.1 (4.31)***
Constant	−7128 (2.92)***	−6459 (2.21)**	−6619 (2.83)***	−5878 (2.71)***
Observations	114	114	114	113
R^2	0.68	0.67	0.69	0.68

Notes: Robust t-statistics below estimates given in Equations (1) and (3); robust z-statistics given in Equations (2) and (4). ***Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and *Stat. sig. at 90 percent level.

In regard to the measures of strategic interaction, we see evidence for positive reaction functions. All strategic interaction coefficients are positive. Only one is not statistically significant at the 90 percent or greater level (but is significant at the 89 percent level or greater). Generally, the best fit for the strategic interaction variables are when they were lagged one period. The contemporaneous variables are not statistically significant.

The coefficient estimates appear plausible. For both New York and Chicago's count, the one-year lag values are around the 0.20–0.25 range, suggesting inelastic responses. For the maximum height values, we see that New York adds about 1.2 m to its height when there is a 10 m increase in Chicago's height. Chicago's response is greater; with every 10 m added in New York, Chicago responds by adding about 2.6 m, one year later.

Based on the size of the coefficients we do not see strong evidence that Chicago suffers from a Second City Syndrome. For the completions equations, New York's response to Chicago's construction is larger. However, for the maximum height, we see evidence that Chicago's height is more responsive than New York. But given the variation of coefficient estimates across specifications, the paper does not provide strong evidence that Chicago

TABLE 6: Regression Results for Chicago's Maximum Height (meters)

	(1) OLS	(2) 2SLS	(3) OLS	(4) SURE
ln(RGDP) Detrended$_{t-2}$	231.2 (3.66)***	220.9 (3.99)***	222.1 (3.42)***	197.3 (3.11)***
ln(FIRE)$_{t-2}$	67.9 (2.56)**	67.2 (2.71)***	70.6 (2.45)**	65.1 (2.34)**
ln(Total Stock)$_{t-2}$	−3.21 (0.20)	−4.18 (0.28)	−7.23 (0.47)	−3.38 (0.23)
ln(Materials Cost)$_{t-2}$	−92.3 (1.14)	−77.9 (0.94)	−47.8 (0.68)	−40.0 (0.64)
ln(Stock Volume)$_{t-2}$	−4.61 (1.28)	−4.28 (1.24)	−3.76 (1.10)	−3.61 (1.14)
ln(Metro. Pop.)$_{t-2}$	112.9 (1.77)*	104.6 (1.76)*	94.7 (1.50)	66.4 (1.09)
%ΔRE Loans$_{t-3}$	0.545 (0.82)	0.550 (0.90)	0.705 (1.12)	0.727 (1.18)
%ΔS&P Index$_{t-3}$	−0.585 (2.03)**	−0.567 (2.11)**	−0.525 (1.83)*	−0.487 (1.78)*
Interest Rate$_{t-3}$	2.25 (2.28)**	2.09 (2.17)**	2.00 (1.95)*	1.78 (1.87)*
Zoning Height Restrictions$_{t-2}$	−13.2 (0.86)	−13.6 (0.92)	−13.7 (0.87)	−12.4 (0.79)
Zoning FAR Limits$_{t-2}$	−42.9 (1.35)	−42.6 (1.43)	−46.1 (1.52)	−34.1 (1.12)
NYC Max. Height$_t$		0.075 (0.48)		
NYC Max. Height$_{t-1}$			0.185 (1.23)	0.256 (2.09)**
Chi Max. Height$_{t-1}$	0.242 (1.72)*	0.225 (1.60)	0.195 (1.60)	0.206 (2.17)**
ln(Plot Size)	11.1 (5.81)***	10.6 (5.34)***	9.39 (4.36)***	9.07 (6.95)***
Constant	−1747 (1.95)*	−1625 (1.96)*	−1480 (1.67)*	−1071 (1.25)
Observations	113	113	113	113
R^2	0.69	0.69	0.71	0.70

Notes: Robust t-statistics below estimates given in Equations (1) and (3); robust z-statistics given in Equations (2) and (4). ***Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and *Stat. sig. at 90 percent level.

TABLE 7: χ^2-tests for Significance of the Zoning Coefficients

Variable	χ^2-Stat	P-Value
ln(1+Count)$_{NYC}$	7.50	0.02
ln(1+Count)$_{Chi}$	6.22	0.04
Max$_{NYC}$	4.34	0.11
Max$_{Chi}$	1.32	0.52

Note: Tests are based on coefficients from the SURE.

acted "like a kid picking a fight with the toughest punk on the corner" (Hayner, 2000, p. 212).

Effects of Zoning Regulations on the Other City

In the above section, the results show that each city has responded positively to the building decisions in the other city. However, as Shultz and Simmons (1959) suggest, it may be that part of this positive response comes from zoning regulations. If one city's zoning restrictions are the other city's gain, this might appear via a positive reaction function. The purpose of this section is thus twofold. First, it aims to see if the reaction functions remain positive after "netting out" the other city's zoning variables. If so, it

TABLE 8: Coefficients for Zoning Variables Included in Other City's Equation

New York City			Chicago		
	Count	Max		Count	Max
$y_{Chi,t-1}$	0.22 (4.12)***	0.05 (0.51)	$y_{NYC,t-1}$	0.19 (2.51)**	0.30 (2.49)**
Chi Height Restriction$_{t-4}$	1.03 (4.31)***	58.2 (2.44)**	NYC Zoning 1916$_{t-4}$	0.11 (0.56)	75.3 (3.09)***
Chi FAR Limits$_{t-4}$	0.51 (1.69)*	16.1 (0.65)	NYC Zoning 1961$_{t-4}$	0.42 (1.28)	124.9 (3.09)***
χ^2-statistic	26.7	6.87		2.51	10.7
P-value	0.00	0.03		0.29	0.01

Notes: Coefficients are from the SURE. The other coefficient estimates not presented. Robust z-statistics below estimates. ***Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and *Stat. sig. at 90 percent level.

provides further evidence of strategic complementarity. In addition, I test to see if zoning regulations in once city influence the other city. If there is a positive effect from zoning then it also suggests that skyscrapers are strategic substitutes as well as complements, since zoning restrictions in one city will reduce heights in that city, which can then lead to increases in height in the other.

As an example, let's say we observe the effect of Chicago's zoning changes on Chicago's skyline with a two-year lag, and further we see a one-year lag in the response by New York to changes in Chicago's skyline, then we would expect, all else equal, to see that changes in Chicago's zoning regulations would impact New York's skyline three years later. One simple way to test for the effect of zoning in one city on the other is to include long lags of the other city's zoning changes as a right-hand side variable, and still include all of the other variables presented in Tables 3–6. The idea is to test how a city reacts to that part of the other city's height decision that is due to zoning, controlling for all the other factors that determine a city's height. To perform these tests, I reran the SURE system, but I also included the other city's zoning dummy variables in each equation, but lagged four years. For brevity, Table 8 presents only the zoning coefficient estimates and the lag-dependent variable of the other city.

A few notes are in order. First, this is clearly a highly simplified exercise since I am testing if restrictions in one city are correlated with changes in height in the other city. I leave more sophisticated, causal tests for future work. Second, the table presents the fourth lag of the other city rather than third lag, as would be implied from the findings reported above. The reason is that the fourth lag provided a better fit than then third lag (in terms of larger χ^2-statistics), though qualitatively the results are similar (and are available upon request).

First the results show that the other city's lag-dependent variables remain positive and statistically significant, which provides evidence for the robustness of the positive reaction functions. Second, we see that the other city's zoning regulations are generally positive and statistically significant. This suggests that skyscrapers also have an element of strategic substitutability.

An Additional Robustness Test

Table 9 provides the results of another robustness test. In this case, I reran the SURE but in each equation I included a national real estate measure as well. The aim is to see if the inclusion of these national variables changes the statistical significance, size, or sign of the strategic interaction variables. Large changes in the strategic variables

TABLE 9: Coefficients of Strategic Variables and National Variables from SURE

	ln(1+Count)$_{NYC}$	ln(1+Count)$_{Chi}$	Max$_{NYC}$	Max$_{Chi}$
Other City's Dep. Var.$_{t-1}$	0.257 (4.41)***	0.183 (2.14)**		0.388 (3.28)***
Other City's Dep. Var.$_{t-2}$	0.104 (1.72)*		0.114 (1.26)	
National Variable$_{t-1}$	0.091 (0.87)	−0.044 (0.64)		0.173 (1.81)*
National Variable$_{t-2}$			0.030 (0.30)	

Notes: Other coefficient estimates not presented. See text for a description of the national variables. Robust z-statistics below estimates.***Stat. sig. at 99 percent level; **Stat. sig. at 95 percent level; and *Stat. sig. at 90 percent level.

would suggest that they are really capturing changes in real estate cycles rather than strategic interaction *per se*. For the count regressions, I include an index of the detrended real value of nonresidential construction in the United States. For the *max* variable, I include the height of the tallest building completed among 12 other cities in the United States (see Appendix A for more details about each variable). For brevity, the table only presents the national and strategic variables (the rest of the results are available upon request). For each dependent variable, I used the same lag structure for the national variables as the strategic variable. The results show that the inclusion of the national variables do not dramatically alter the results, with no sign changes and generally no loss of statistical significance. Thus, this test provides further evidence of casual relationships for the strategic interaction variables.

6. CONCLUSION

This paper has investigated the market for skyscrapers in New York City and Chicago from 1885 to 2007. The urban economics literature has generally been silent on interurban competition, yet it is widely believed that these two cities are economic rivals. Despite the large number of historical and architectural accounts of skyscrapers, no work in economics has tested the competition hypothesis.

Because skyscrapers can be used for multiple purposes, skyscraper height can be strategic substitutes, complements or both. Since skyscrapers are used to house economic activity, if one city builds more or taller buildings, it will reduce the price of space and can, therefore, lead to the other city reducing its space as a best response. On the other hand, since cities often want to have taller or more buildings than their rivals for reasons of ego, advertising or local pride, builders can positively respond to the height decisions in the other cities.

Looking at time series data, this paper finds evidence for both positive and negative strategic effects. Most importantly, estimated reaction functions show positive responses to the other city's strategic variable, providing evidence for the strategic complements hypothesis. In regard to zoning, the evidence supports that zoning regulations in each city have been binding, causing builders to reduce construction because of these regulations. In addition, I also find evidence that there is a strategic nature to height regulations. Chicago and New York have both positively responded to height restrictions in the other city (with several years lag); these positive reactions provides support for the strategic substitutes model.

Since the economics of skyscrapers remains an understudied area, there are many possible extensions for future work. One area includes how the number and density of skyscrapers has affected the growth of cities over the twentieth century. The work here can also be expanded to include more cities to see if there is evidence of multicity competition with regard to skyscraper height.

APPENDIX A: DATA SOURCES AND PREPARATION

- *Completions, Maximum Heights, and Net Cumulative Completions:* http://www.skyscraperpage.com and http://www.emporis.com. Year of demolitions were found from *New York Times* or Randall (1999).
- *Plot Size:* New York City: http://gis.nyc.gov/doitt/nycitymap/ and various editions of the *Manhattan Land Books*. Chicago: Sanborn Fire Insurance Maps and http://maps.cityofchicago.org/kiosk/mpkiosk.jsp.
- *Detrended GDP:* Annual real GDP is from Johnston and Williamson (2010). ln(Real GDP) was regressed on the year. The residual of this regression is the variable used.
- *GDP Deflator:* 1890–2007: Johnston and Williamson (2010).
- *Percent of National Employment in FIRE:* 1900–1970: FIRE data from Table D137, *Historical Statistics* (1976). Total (nonfarm) Employment: Table D127, *Historical Statistics*. 1971–2007: FIRE data from BLS.gov Series Id: CEU5500000001 "Financial Activities." Total nonfarm employment 1971–2007 from BLS.gov Series Id:CEU0000000001. The earlier and later employment tables were joined by regressing overlapping years of the new employment numbers on the old employment numbers and then correcting the new numbers using the OLS equation; this process was also done with the FIRE data as well. 1890–1899: For both the FIRE and total employment, values were extrapolated backwards using the growth rates from the decade 1900–1909, which was 4.1 percent for FIRE and 3.1 percent for employment.
- *Index of Real Materials Costs:* Construction Cost Index: 1947–2007: 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 created by dividing the construction cost index by the GDP Deflator for each year.
- *Regional Populations:* U.S. Census Bureau. For New York: Population included the five boroughs of NYC, Nassau, Suffolk, Westchester, Hudson, and Bergen counties. For Chicago, population was from Cook, DuPage, Kane, Lake, Will, and Lake (Ind.) counties. Annual data are generated by estimating the annual population via the formula $pop_{i,t} = pop_{i,t-1}e^{\beta_i}$, where i is the census/data year, i.e., $i \in \{1890, 1900, \ldots, 2000, 2007\}$, t is the year, and β_i is solved from the formula, $pop_i = pop_{i-1}e^{10*\beta_i}$.
- *Percent Change in Real Estate Loans:* 1896–1970: Table X591, "Real Estate Loans for Commercial Banks." *Historical Statistics.* 1971–2007: FDIC.gov Table CB12, "Real Estate Loans FDIC-Insured Commercial Banks." The two series were combined without any adjustments. For 1885–1895: 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.
- *Percent Change in Standard and Poor's Stock Index*: *Historical Statistics* (2006), Millennial Edition Online; http://finance.yahoo.com/.
- *Real Interest Rates:* Nominal interest rate: 1890–1970: Table X445 "Prime Commercial Paper 4–6 months." *Historical Statistics.* 1971–1997: http://www.federalreserve.gov, 1998–2007: 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 1997–2007. Inflation is the percentage change in the GDP deflator.

- *Stock Exchange Volumes:* New York: http://www.nyse.com/. Chicago: Palyi (1937/1975) and various SEC Annual Reports.
- *Detrended Index of Real Value of U.S. Nonresidential Real Estate:* 1880–1931: *Historical Statistics*, Table Dc131; 1915–1964: Table Dc282; 1964–1999: Table Dc303; 1993–2007: http://www.census.gov/const/C30/privpage.html (Total Private Nonresidential Construction). To join the first two series, I ran a regression of the first on the second for overlapping years, and extended the first series using predicted values. To join the third series, I took the ratio of the third series to the longer series for 1964 and adjusted the series using that ratio value. Similarly, to join the fourth series, I took the ratio of the fourth series to the longer series for 1999 and adjusted the longer series accordingly. Then, I created a real value by dividing the series by the GDP Deflator. Finally, I detrended the series by regressing the log of the real estate series on a time trend and I used the residual as the series.
- *Maximum Skyscraper Height for 12 U.S. Cities.* For Atlanta, Boston, Cleveland, Dallas, Detroit, Houston, Los Angeles, Miami, Philadelphia, Pittsburgh, San Francisco, and Seattle, the largest building completed each year was downloaded from http://www.emporis.com and http://www.skyscraperpage.com (accessed June 2010). For the time series, the largest building completed among the chosen cities was selected. These cities were chosen based on the fact that they contain many skyscrapers and are geographically diverse.

APPENDIX B: STATISTICAL TESTS

This appendix provides the results of additional tests. Table B1 provides the *P*-values for the Breusch–Pagan test for heteroskedasticity and the Breusch–Godfrey LM test for serial correlation for each equation.

TABLE B1: Results of Breusch–Pagan Test for Heteroskedasticity and the Breusch–Godfrey LM Test for Serial Correlation for Regressions Presented in Section 5

Dep. Var.	Equation	Heteroscedasticity	Serial corr.
$\ln(1+\text{Count})_{NYC}$	(1)	0.11	0.26
$\ln(1+\text{Count})_{NYC}$	(2)	0.19	0.18
$\ln(1+\text{Count})_{NYC}$	(3)	0.01	0.11
$\ln(1+\text{Count})_{NYC}$	(4)	0.01	0.05
$\ln(1+\text{Count})_{Chi}$	(1)	0.00	0.35
$\ln(1+\text{Count})_{Chi}$	(2)	0.00	0.49
$\ln(1+\text{Count})_{Chi}$	(3)	0.00	0.19
$\ln(1+\text{Count})_{Chi}$	(4)	0.00	0.53
Max_{NYC}	(1)	0.00	0.94
Max_{NYC}	(2)	0.00	0.80
Max_{NYC}	(3)	0.00	0.75
Max_{NYC}	(4)	0.00	0.91
Max_{Chi}	(1)	0.00	0.43
Max_{Chi}	(2)	0.00	0.46
Max_{Chi}	(3)	0.00	0.09
Max_{Chi}	(4)	0.00	0.11

Note: P-values given in the table.

In the twocases where the Breusch-Godfrey LM test for serial correlation rejected the null hypothesis of no serial correlation at the 90 percent or greater level, two additional tests were run. First, I ran an AR(1) of the residuals and tested the lagged coefficients. In both cases, the lagged coefficients were statistically insignificant. Second, I ran the Portmanteau test for white noise. In both cases, I could not reject the null hypothesis of white noise for the residuals.[26] Thus, both alternative tests indicate that serial correlation is not a significant problem.

Table B2 presents results of the instrumental variable tests.

TABLE B2: Results of Instrumental Variable Tests

Variable	Endog. (Durbin)	Overid. (Sargan)	First Stage F-stat.	F-stat. P-value
Count_{NYC}	0.03	0.84	26.45	0.000
Count_{Chi}	0.00	0.69	54.31	0.000
Max_{NYC}	0.44	0.24	7.85	0.001
Max_{Chi}	0.63	0.21	10.36	0.000

Note: Columns 2, 3, and 5 are *P*-values.

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[26]For the AR(1) equation, we have a *P*-value of 0.135 for the residuals from NYC Count Equation (4), and 0.541 for Chicago Max Equation (3). For NYC Count Equation (4), the *P*-value for the Portmanteau test is 0.67; for Chicago Max (3) it is 0.88.

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