Is Terrorism Eroding Agglomeration Economies in Central Business Districts? Lessons from the Office Real Estate Market in Downtown Chicago

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Abstract

The attacks of September 11, 2001 and more recently the Madrid and London downtown train bombings have raised concerns over both the safety of downtowns and the continuous efforts by terrorists to attack such high density and significance areas. This article employs building-level data on vacancy rates to investigate the impact of an increased perception of terrorist risk after 9/11 on the office real estate market in downtown Chicago. Chicago provides the perfect laboratory to investigate the effects of an increase in the perceived level of terrorism risk in a major financial district. Unlike in New York, the 9/11 attacks did not restrict directly the available office space in downtown Chicago. Moreover, the 9/11 attacks induced a large increase in the perception of terrorism risk in the Chicago Central Business District, which includes the tallest building in the U.S. (the Sears Tower) and other landmark buildings which are potential targets of large-scale terrorist attacks. Our results show that, following the 9/11 attacks, vacancy rates experienced a much more pronounced increase in the three most distinctive Chicago landmark buildings (the Sears Tower, the Aon Center and the Hancock Center) and their vicinities than in other areas of the city of Chicago. Our results suggest that economic activity in Central Business Districts can be greatly affected by changes in the perceived level of terrorism.

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1. Introduction


The increase in the perceived level of terrorist risk induced by the 9/11 attacks has placed particularly large pressures on major Central Business Districts, such as New York, London, or Chicago, which are considered to be preferred targets of terrorist attacks because of their high population density, economic significance, and because they contain symbolic targets such as landmark buildings or government facilities. The susceptibility of Central Business Districts to large-scale terrorist attacks (as well as their vulnerability, as demonstrated by recent events) is particularly unsettling given the crucial role that Central Business Districts play in economic activity. Quite surprisingly, however, there is very little work available on the effects of terrorism on Central Business Districts. This article tries to fill that void. For this purpose, we use building-level data from downtown Chicago, one of the most significant Central Business Districts in the U.S., to investigate the economic impact of an increase in the perception of the risk after 9/11.

There are two main channels through which terrorism affects economic outcomes. First, terrorist attacks have a direct effect on the economy because they destroy productive capital (physical and human). Because the destruction caused by terrorist attacks represents only a small fraction of the total stock of productive capital, Becker and Murphy (2001) have argued that the relative importance of this effect is small in practice. Second, terrorism increases the level of fear and uncertainty, which may have large effects on the behavior of economic agents (see Abadie and Gardeazabal, 2005, and especially Becker and Rubinstein, 2004).

The Central Business District (CBD) of Chicago provides the perfect laboratory to investigate the effects of an increase in the perceived risk of terrorism on a major financial
center. The city of Chicago was not directly affected by the destruction of the 9/11 attacks. However, the 9/11 attacks induced a large increase in the perception of terrorism risk in the Chicago Central Business District, which includes the tallest building in the U.S. (Sears Tower) and other landmark buildings. The case of Chicago is, therefore, of particular interest, because it allows us to separate the direct impact of terrorist attacks on available office space (absent in Chicago during the 9/11 events) from the impact caused by an increased perception of terrorist threat in Central Business Districts after 9/11.

A distinctive characteristic of this study is that it uses data disaggregated at the building level on a quarterly basis for a panel of Class A and Class B office buildings (as defined by CoStar Group, see below) in the downtown area of Chicago. To our knowledge, data analysis of the impact of terrorism on real estate markets has never been done at this breadth and scale.

To detect the impact of an increase in the perception of terrorism risk in Chicago as a result of 9/11, we compare the evolution of vacancy rates at the three main landmark buildings of Chicago (the Sears Tower, the Aon Center, and the Hancock Center) and other nearby office buildings within a “shadow” area of 0.3-mile of the three landmark buildings to the evolution of vacancy rates of office buildings located outside the shadow areas of the three landmark buildings. We use panel data fixed-effects estimators to control for the presence of unmeasured characteristics of each individual building in our sample. Our dataset includes quarterly data for Class A and Class B office buildings in downtown Chicago during the period of 1996-2006. Office buildings are classified as Class A because of their amenities, design, location, building efficiency, management quality and other property characteristics which make them unique in the market and highly desirable for tenants who are willing to pay the highest market rents. Class B properties do not feature the special or innovative characteristics or the highly efficient floor plates that are often found in Class A buildings. They are appealing to a tenants' base with lower quality demands and more severe budgetary constraints than those who lease Class A properties.1 We selected the Sears Tower, the Aon Center, and the Hancock Center as “anchor” buildings because of their landmark stature, which makes them preferred targets of terrorist attacks. We based our choice of a 0.3-

1 Other buildings of lower quality than Class B buildings are classified as Class C in the CoStar database. For comparability reasons, we do not include Class C buildings in our sample. The exact CoStar definitions of Class A, B, and C are included in the appendix.
mile radius for the shadow areas on the spread of the massive debris in New York City after the 9/11 attacks (Dermisi, 2006).

Our results show that office vacancy rates increased in downtown Chicago in the wake of the 9/11 attacks. Most importantly, office properties in the three main Chicago landmark buildings and the surrounding areas experienced more severe increases in vacancy rates than office properties not located in the vicinities of landmark buildings. These results suggest that the higher perceived level of terrorism risk in Chicago after 9/11 induced centrifugal forces powerful enough to counteract the effects of agglomeration economies and knowledge spillovers. This is particularly disturbing given the crucial role of Central Business Districts in exploiting agglomeration economies and knowledge spillovers (Glaeser et al, 1992).

The rest of the article is organized as follows. Section 2 reviews the literature on the impact of terrorism in cities. Section 3 describes in detail our dataset and methodology. Section 4 presents and discusses our empirical results. Section 5 concludes.

2. Terrorism in Cities
Long before the 9/11 events, terrorism had inflicted a large number of human losses and severe physical destruction in major urban centers around the world, such as London, Istanbul, and Jerusalem. In fact, as Savitch and Ardashev (2001) indicate, not only terrorism is more prevalent in cities than in rural areas, but also the number of incidents and the magnitude of the physical damage created by terrorism in urban areas has increased steadily in recent years. Savitch and Ardashev (2001) provide four main reasons for why cities are selected by terrorists for their attacks. First, cities represent what in military terms are called “target-rich environments”. They contain a high density and a heterogeneous mix of valuable assets, including numerous human targets and large infrastructures. Second, global economic interdependence hinges on the role that cities play as communication nodes and command centers. Third, the high population density and heterogeneity that is characteristic of urban areas often implies that antagonistic groups are located in close geographic proximity. As a result, some cities have become nesting grounds for terrorist organizations. Savitch and Ardashev (2001) mention Beirut and Belfast among other examples of this phenomenon. Finally, cities have substantial symbolic value as terrorist targets.
In addition to the four explanations offered by Savitch and Ardashev (2001) for why cities are preferred targets for terrorism, it should be pointed out that cities might be particularly vulnerable to terrorist actions. The large number of individuals and goods traveling into cities often makes security measures too costly or impractical. In addition, cities allow terrorists to “hide in the crowd”.

Although terrorism is not new to cities, the 9/11 attacks massively increased the perceived level of terrorism risk in Central Business Districts. The New York downtown office market was severely impacted on 9/11, with 44 percent of Manhattan’s downtown Class A space destroyed by the attacks, according to the City of New York (2001). The Government Accounting Office (2002) estimated the effects of the 9/11 attacks on New York City at “about $83 billion in lost output, wages, business closings, and spending reductions,” (Eisinger, 2004).

Surveys of building owners and managers provide direct evidence of an increased perception of terrorism risk in Central Business District as a result of the 9/11 attacks, which resulted in enhanced security measures. The introduction of better or additional building security measures in response to 9/11 led to security spending increases. Chapman (2004) estimated that U.S. security spending by private office building owners/managers rose from 49 cents per square foot in 2001 to 55 cents per square foot in 2003, a 12-percent increase. For certain trophy buildings, such as the Sears Tower, the increases were even more pronounced. Security costs at Chicago’s Sears Tower increased from 39 cents per square foot per year immediately before 9/11 to 1.05 dollars per square foot per year afterwards. In 2004 the security costs throughout the U.S. for Class A downtown buildings averaged to 71 cents per square foot per year regardless of the size of the building (BOMA, 2005). However, security costs were substantially lower for firms located outside major urban centers.

It is therefore not surprising that after 9/11 many real estate markets analysts expressed their concerns about the potential impact of an increase of terrorist risk in cities.

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3 The pre-9/11 figure is based on security costs in the Sears Tower for the period between January 1, 2001 and Sept. 11, 2001. The post-9/11 figure is based on security costs in the Sears Tower for the period 2002-2004. These figures were conveyed to us in personal communication with Carlos Villarreal, Vice President of National Security and Life Safety of Trizec Properties and former Director of Security of the Sears Tower.
4 Kinum (2005) estimate that moving 15 to 20 miles outside the city can reduce security costs for a company by as much as 60 percent.
(see, e.g., Berube and Rivlin, 2002). However, apart from documented increases in security costs after 9/11 and beyond the direct destruction that resulted from the attacks, to date empirical researchers have not yet detected evidence of a substantial impact of terrorism in cities. After analyzing historical data for cities affected by war or terrorism, Glaeser and Shapiro (2002) argue that while the effects of 9/11 on the lower Manhattan area are likely to be large, other urban areas in the U.S. may largely be unaffected. Based on data on mass transit ridership and commercial real estate trends before and immediately after 9/11, Dittmar and Campbell (2002) argue that the 9/11 attacks were unlikely to encourage neither sprawl nor migration outside dense metropolitan areas. In addition, using simulation analysis for New York City, Harrigan and Martin (2002) reach a similar conclusion about the resilience of cities to catastrophic events.

Of course, as other analysts have pointed out, the resilience of cities to terrorism depends on the intensity of terrorism risk. Along these lines, Mills (2002) argues that the value of economies of agglomeration for Central Business Districts could erode as a result of the 9/11 attacks. Mills (2002) suggested also that rents on tall office buildings would be negatively affected. Johnson and Kasarda (2003) indicate that after 9/11 commercial real estate brokers and corporate relocation consultants reported an increasing number of their clients expressing aversion to locating in trophy buildings and in close proximity to them, as well as “near other large gathering venues (stadiums, arenas, major retail establishments), energy generating facilities, and infrastructure projects (bridges, tunnels, natural gas pipelines, water and sewer plants).” A survey in Miller et al. (2003) showed that after 9/11 tenants were more concerned with the profile of their co-tenants and preferred to avoid companies or agencies that might be possible terrorist targets. Miller et al. (2003) contains also the only quantitative analysis that we are aware of on the effects of the higher perception of terrorism risk in cities created by the 9/11 attacks. Miller et al. (2003) analyze data for a sample of tall and trophy buildings in 10 U.S. cities. They fail to find significant evidence of an impact of the 9/11 attacks, with the exception of an increase sublet activity for a small set of “truly famous” trophy buildings. However, the time data horizon of the regressions in Miller et al. (2003) does not go beyond the fourth quarter of 2001, only a few months after the 9/11 attacks. They caution the reader that “[t]his study is preliminary in that the lasting effects of 9/11 will not be known until much more time has elapsed.”
There are two potential explanations for the limited amount of empirical evidence of the effect of terrorism in cities. First, appropriate data sources to analyze the effect of terrorism in cities (e.g., commercial real estate databases) are expensive and difficult to access, which limits the amount of research in this area. Second, given the pervasiveness of long-term leases in office markets, as pointed out by Miller et al. (2003) and Johnson and Kasarda (2004), the true magnitude of the impact of terrorism can only be detected after a prolonged adjustment period. In particular, Johnson and Kasarda (2004) suggest that the full extent of effect of the 9/11 attacks on business activity in cities would not detectable until 2004 and maybe later, when many longer-term commercial real estate leases expire.

3. Data Sources and Methodology
The data for this study come from the CoStar Group. The CoStar Group database is the only nationwide commercial real estate database reporting panel data on rents and vacancy rates at the building level, along with other building characteristics like location and height. The CoStar Group database provides a “comprehensive inventory of office and industrial properties in 50 U.S. markets” (CoStar Group, 2006) with data reported on a quarterly frequency. For this study, we used the CoStar Group data for the city of Chicago.

We restrict our sample to Class A and Class B office buildings within the extended Central Business District of Chicago. The sample period of the data used in our analysis spans from the second quarter of 1996 to the second quarter of 2006. We discard from our dataset office buildings that were constructed, renovated, converted to condos, or demolished during our sample period or immediately before. We also discarded three additional buildings for other miscellaneous reasons. Our final dataset is a balanced panel with a total of 242 individual building in downtown Chicago.

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5 Access to the CoStar Group database was provided to us by the Building Owners and Managers Association (BOMA) of Chicago.
6 As discussed below, data on rents reflect only asking rents for available office space, rather than average rent.
7 More concretely, the study area focuses on the extended Central Business District (CBD) of Chicago with the following borders: Division Street (North), Ashland Avenue (West), Roosevelt Road (South) and the Lake Michigan (East).
8 The first one of them seems to be totally vacant during most of the sample period due to litigations. The second one becomes owner-occupied during our sample period. Finally, the third of these three office buildings was converted to retail space in 2006.
We classify each building in our dataset into two categories depending on whether or not the building is located in the “shadow areas” of the three main Chicago landmark buildings: the Aon Center, the Hancock Center, and the Sears Tower. Shadow areas are defined as the areas of 0.3-mile radius surrounding any of the three Chicago landmark buildings. Figure 1 shows the location of all the buildings in the original CoStar database along with the three landmark building shadow areas.

The Sears Tower, the Aon Center and the Hancock Center are among the tallest buildings in the U.S. Two of them, the Sears Tower and the Aon Center, are almost exclusively office buildings with a small retail component. In contrast, the Hancock Center includes a significant residential component. The Sears Tower (1,451 feet and 110 floors) is the tallest building in the U.S., the Aon Center (1,136 feet and 83 floors) is the third tallest in the U.S., and the Hancock Center (1,127 feet and 100 floors) is the fourth tallest in the U.S. The three buildings belong to different real estate submarkets within the downtown area of Chicago (as defined by the CoStar Group). More specifically, the Sears Tower is located in the West Loop submarket, the Aon Center is part of the East Loop submarket, and the Hancock Center is part of the Michigan Avenue submarket. Our study area, however, expands beyond these three submarkets and includes six additional CoStar Group submarkets: Central Loop, South Loop, LaSalle Street, River North, River West and Gold Coast. The choice of a 0.3-mile radius to define the extent of the shadow areas was motivated by the extent of the debris fields caused by the collapse of the World Trade Center on 9/11.9

Adopting a 0.3-mile radius to define the shadow areas, the Sears Tower’s shadow area includes 17 Class A buildings and 23 Class B buildings. The Aon Center’s shadow area includes 7 Class A buildings and 4 Class B buildings. Finally, the Hancock Center’s shadow area includes 5 Class A and 10 Class B buildings. Beyond the shadow areas of the three trophy buildings our data set includes 23 Class A buildings and 153 Class B buildings. In total our study uses data on 52 Class A buildings and 190 Class B buildings.

Our building dataset includes the following CoStar Group variables among others: latitude, longitude, building height, rentable building area, submarket, vacancy rates, and

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9 Risk Management Solutions (2001) reports that the collapse of the World Trade Center created a massive debris area up to 1,300 feet (or 0.25 miles) from the World Trade Center, with thick airborne debris traveling up to 0.5 miles. Based on the particular characteristics of downtown Chicago, Dermisi (2006) estimates that the collapse of one of the three anchor buildings in downtown Chicago would produce massive debris up to a distance of 0.3 miles from the building.
gross rents. Gross rents are expressed in current values and they reflect asking rents for office space currently marketed for lease. We use the Harversine formula and data on the latitude and longitude of each building to calculate the distances between each of the buildings in our sample and the trophy buildings.

We use fixed effects estimators to study the impact of 9/11 on the shadow versus non-shadow areas of our study. Our basic regression specification is:

\[
\text{vacancy rate}_{it} = \alpha (\text{shadow}_i \times \text{post-9/11}_t) + f(t) + \eta_i + \epsilon_{it}
\]

where vacancy rate_{it} is the vacancy rate in building i and quarter t, shadow_i \times post-9/11_t is a dummy variable that takes value one if building i is located in the shadow area of a landmark building and the quarter of the observation, t, is after 9/11. In other words, shadow_i \times post-9/11_t takes value one if the building is located in an area that experienced a large increase in the perceived risk of terrorism as a result of the 9/11 attacks and the time period is after 9/11. The function f(t) is a time trend, representing common shocks to the Chicago office markets. In particular, f(t) tries to capture the overall economic and business trends in the city of Chicago during the sample period of our study. The variable \eta_i represents time-invariant building-specific characteristics for building i, such as building location, or floor plan characteristics. Finally, \epsilon_{it} represent building-specific transitory shocks. In our estimators, all observations are weighted using the buildings’ rentable areas. The parameter \alpha measures the difference between changes in vacancy rates experienced around 9/11 in shadow areas and changes in vacancy rates experienced around 9/11 in non-shadow areas.

Under the assumption that, in the absence of 9/11, shadow and non-shadow areas would have experienced similar office real estate market trends, \alpha allows us to detect whether or not the 9/11 attacks impacted the office real estate market in downtown Chicago. More concretely, if the 9/11 attacks eroded agglomeration economies in downtown Chicago, then we expect that \alpha is positive.

Notice, however, that although a non-zero \alpha allows us to detect the influence of 9/11 on the Chicago office real estate market, the value of \alpha does not necessarily identify the magnitude of such effect. The magnitude of \alpha would be inflated relative to the effect of 9/11 in shadow areas if office tenants moved from shadow areas in Chicago to outside shadow areas.
areas in Chicago in response to the higher perception of terrorist threat after 9/11. However, such bias would only enhance the statistical power of our tests for the hypothesis of no effect. The reason is that, if there was substitution between shadow and non-shadow areas in Chicago after 9/11, the comparison of buildings inside and outside the shadow areas incorporates two potential effects of terrorism: the negative effects in the shadow areas and the positive effects through substitution outside the shadow areas. It is also possible, however, that $\alpha$ includes an attenuation bias relative to the effect of 9/11 in shadow areas. That would be the case if there was little or no substitution between shadow and non-shadow areas in Chicago in response to the 9/11 attacks, and if the terrorist attacks had a negative impact on the office real estate markets in non-shadow areas (e.g., because they affected the overall economic conditions). Then, $\alpha$ would under-estimate the impact of the 9/11 attacks on the office vacancy rates at the main three Chicago landmark buildings and other nearby Class A and Class B buildings. However, even if the 9/11 attacks had a negative impact on the office real estate markets in non-shadow areas (through their effects on the overall economic conditions), because the increase in the perception of terrorism was arguably higher in the landmark building shadow areas than in the rest of Chicago, our statistical tests will preserve power to reject the null of no effect.

To further substantiate our results, we use a dose-response design in which the variable that represents that the building is exposed to high perceived risk of terrorism is constructed as the interaction between an after 9/11 dummy and the distance to the closest anchor building:

$$\text{vacancy rate}_{it} = \alpha(\text{distance to anchor}_i \times \text{post-9/11}_t) + f(t) + \eta_i + \epsilon_{it},$$

(2)

where distance to anchor$_i \times$ post-9/11$_t$ is the interaction between the distance of building $i$ and the closest of the Sears Tower, the Aon Center, and Hancock Center and a binary variable which takes the value one after 9/11.

Arguably, however, the distance to the non-shadow area may be more strongly related to the perceived level of terrorism at any particular location after 9/11 than the distance to the anchor buildings. That would be the case if the distance to the anchor buildings is an important factor determining the level of perceived risk within shadow areas while the perceived risk of terrorism does not vary much once the building is located outside the shadow areas. This possibility motivates the following specification:
vacancy rate_{it} = \alpha (\text{distance to non-shadow area}_{i} \times \text{post-9/11}) + f(t) + \eta_{i} + \varepsilon_{it}, \quad (3)

Finally, we estimate an alternative dose-response design in which we use buildings’ heights to measure the perceived level of terrorist risk:

\text{vacancy rate}_{it} = \alpha (\text{height}_{i} \times \text{post-9/11}) + f(t) + \eta_{i} + \varepsilon_{it}. \quad (4)

4. Data Analysis

4.1. Main Results

Figure II shows average quarterly vacancy rates in Chicago shadow and non-shadow areas from the second quarter of 1996 to the second quarter of 2006. The plot of these two vacancy series reveals that vacancy rates in shadow and non-shadow areas evolved very similarly before 9/11, which suggests that both were affected by the same market trends. However, a radically different behavior arose in the wake of the 9/11 attacks. After 9/11 vacancy rates experienced a large increase inside shadow areas. Outside shadow areas vacancy rates experienced also an increase during the year 2002, but they stabilized and even decreased slightly afterwards. Remarkably, while the two series followed each other very closely before 9/11, after 9/11 vacancy rates were consistently higher for offices in or nearby landmark buildings. The pattern of the series in Figure II is therefore consistent with the hypothesis of a more severe impact of 9/11 in those office properties in Chicago in or nearby landmark buildings.

Table I reports descriptive statistics for our sample of office buildings in downtown Chicago. Twenty-seven percent of the buildings in our sample are located inside one of the three shadow areas. Relative to office buildings outside shadow areas, office buildings inside shadow areas are of higher quality, higher height, have more stories, and larger rentable areas, on average. In the first quarter of 2001 the average vacancy rate was approximately 9 percent in shadow areas and 7 percent in non-shadow areas. However, the difference between these two vacancy rates was not significant at conventional test levels. In the first quarter of 2006, more than four years after 9/11, average vacancy rates have increased to 17.4 percent in shadow areas and 12.3 percent in non-shadow areas. The difference in average vacancy rates between shadow areas and non-shadow areas in the first quarter of 2006 was of about 5 percentage points and statistically significant at the 5% level. These figures suggest a deterioration of the office real estate market in downtown Chicago during the period 2001-2006. This deterioration is, however, more pronounced for the three main Chicago landmark
buildings and the buildings close to them. Table I provides also descriptive statistics for rents in our sample of office buildings. These data have to be interpreted with caution because they reflect average asking rents for office space that was marketed for lease at the time of the observation. With this qualification in mind, it is worth noticing that the difference in average rents per square foot between shadow area buildings and non-shadow area buildings narrowed considerably from $4.14 in the first quarter of 2001 to $2.31 in the first quarter to 2006. This variation is also consistent with a deterioration of the office real estate market in the shadow areas, relative to the non-shadow area.

In order to quantify the differences in behavior observed in Figures II for the office real estate market in shadow and non-shadow areas around 9/11, we estimate fixed-effects models that control for the effects of unmeasured building-specific characteristics. Table II reports the estimates for our basic specifications in equation (1) to (4), along with standard errors clustered at the building level. Column (1) reports that around 9/11 vacancy rates increases for office buildings in the shadow areas of landmark buildings were 3 percentage points higher than for buildings outside the shadow areas. The coefficient of the interaction shadow$_i$×post-9/11, indicates that after the 9/11 attacks the deterioration of the real estate market was more severe for office buildings located inside the shadow areas, that is in areas that experienced a higher increase in the perceived terrorism risk.

In columns (2) to (4) of Table II, we use alternative variables to identify the buildings that experienced a large increase in terrorism risk as a result of 9/11. In column (2), we use the distance between the buildings and the closest of the Aon Center, Hancock Center, and Sears Tower as a measure of the magnitude of the change in perceived risk of terrorism as a result of 9/11. The coefficient on the interaction (distance to anchor)$_i$×post-9/11, indicates that, after controlling for other building characteristics, an additional mile of distance to the closest of the three anchor buildings was associated with a 6.17 percentage point lower change in the vacancy rate after the 9/11 attacks.

As explained above, it can be argued that increases in the distance between a building and the closest of the anchor buildings are associated with reductions in terrorist risk only up to the point where the building is located at a safe enough distance from the anchor buildings.

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10 As a result, data on rents are missing for the buildings where no office space became available for lease during the quarter of observation. Notice also that the quality and characteristics of available office space at a building in different time periods may potentially experience significant changes not measured in our data.
To reflect this possibility, in column (3) we use the interaction between distance to the non-shadow area (which is, of course, equal to zero for all the buildings located outside the shadow areas) and a post-9/11 indicator as a measure of the magnitude of the change in terrorism risk after 9/11. Consistent with the results in the previous columns, the coefficient on the interaction (distance to non-shadow area)×post-9/11, is positive and significant. This coefficient indicates that for buildings inside shadow areas, an additional 0.1-mile of distance to the anchor building was associated with a 2.3 percentage point lower increase in the vacancy rate after the 9/11 attacks, after controlling for other building characteristics.

In column (4) building height is used as a proxy for the increase in terrorist risk after 9/11. Regardless of their location relative to other potential targets, tall buildings are often perceived to be preferred targets for terrorist attracts, given the high density of personnel that concentrates in them. Moreover, average evacuation times are long for tall buildings, and therefore terrorist attacks pose a particularly severe threat for them. The coefficient on the interaction between height and a post-9/11 dummy is positive and significant, indicating that in the wake of the 9/11 attacks taller buildings experienced higher increases in vacancy rates. An increase of 1,000 feet in building height is associated with a 5.2 percentage point higher change in the vacancy rate around 9/11.

On the whole, the results in Table II indicate that, in the wake of the 9/11 attacks, buildings with characteristics that made them be perceived as prone or vulnerable to terrorist attacks experienced a particularly severe deterioration in real estate market outcomes. These results suggest that economic activity in Central Business Districts can be greatly affected by changes in the perceived level of terrorism.

### 4.2. Robustness Analysis

In this section, we assess the validity of the results of the previous section using a variety of methods.

First, given the long term nature of lease contracts in office real estate markets, if changes in the perceived levels of terrorism after 9/11 affected the location decision of office tenants in downtown Chicago, this effect could not be instantaneous but cumulative in time (see, e.g., Johnson and Kasarda, 2003). Table III tests this implication of the widespread use of long-term leases on the timing of the effect of terrorism in the office real estate market.
The first column of Table III reports the estimated coefficients for the following fixed-effects model:

\[ \text{vacancy rate}_i = \alpha \times (\text{shadow}_i \times \text{post-9/11}_t) + \delta \times (\text{shadow}_i \times \text{quarters since 9/11}_t) + f(t) + \eta_i + \epsilon_{it}. \]  

The coefficient on the interaction between the shadow area dummy and the number of quarters since 9/11 is positive and significant. However, once the interaction between the shadow area dummy and the number of quarters since 9/11 is included in the model the coefficient on \( \text{shadow}_i \times \text{post-9/11}_t \) becomes small in absolute value and statistically non-significant at conventional test levels. This result is consistent with our expectation that any real estate market reaction to an increase in the level of terrorism could not be instantaneous but cumulative in time.

The models in columns (2) to (4) are analogous to equation (5) but use the distance to the closest anchor building, the distance to the non-shadow area, and the height of the building, respectively, in place of the shadow area dummy. Again, for all these variables we obtain the same qualitative result as in column (1).

Table IV provides a more detailed description of evolution of vacancy rates after 9/11 for buildings with different degrees of exposure to terrorism risk. Column (1) reports the estimated coefficients on the interactions between a shadow area dummy and time dummies for the years 2002 to 2006, along with clustered standard errors. Columns (2) to (4) report analogous statistics for the cases in which distance to the closest anchor building, distance to the non-shadow area, and height of the building, respectively, are used as a proxy of exposure to terrorism risk after 9/11. The coefficients in Table IV shows that the gap in vacancy rates between buildings with different exposures to terrorism risk after 9/11 increased monotonically during the period 2002-2005. With the exception of the last column, where building height is used as a measure of exposure to terrorist risk after 9/11, Table IV indicates a narrowing of the gap in vacancy rates in 2006; something that can be observed also in Figure II.

As argued in more generality in Abadie (2006), the identification conditions behind equations (1) to (4) imply that in the absence of the 9/11 attacks, average vacancy rates trends in Chicago would not have differed depending on the location of the buildings relative to the three main landmark building or on their height. Although this assumption is not
directly testable, it is easy to test the hypothesis that previous to the 9/11 attacks changes in trends in the average vacancy rates did not depend on building locations with respect to the three anchor buildings or on the building height. To test this hypothesis we reproduced the analysis of Table II using pre-9/11 data only. We divided the pre-9/11 sample into two roughly equal periods depending on whether the observation is before or after the last quarter of 1998. Then we proceeded as in Table II but using an after-1998 dummy in place of the post-9/11 dummy. We report the result in Table V. None of the coefficients in Table V is statistically significant at conventional test levels. Table V provides evidence in favor of the hypothesis that, at least previous to 9/11, trends in vacancy rates did not depend on our proxy variables for the severity of the increase in terrorism risk at the building level after 9/11.\textsuperscript{11}

As an additional robustness check, we apply a simple permutation test of significance of the coefficients in Table II. To implement this test, we produced 10,000 random permutations of the values of our measures of post-9/11 exposure to terrorism and recomputed the estimators of Table II for each permutation. We then compared the coefficients obtained in Table II to their permutation distribution. This inferential procedure produces exact test levels regardless of the sample size and the covariance structure of the regression errors, $\varepsilon$.\textsuperscript{12} Figure III shows the permutation distributions of the coefficients on the interactions between our four proxies of the severity of terrorism risk after 9/11 and a post-9/11 dummy, along with one-sided p-values. Figure III demonstrates that there is only a small probability (p-value) of obtaining results like those in Table II, if we permute at random our proxy measures of exposure to terrorism risk after 9/11 among the buildings in the sample.

As a final empirical check of the meaning of our empirical results we plot in Figure IV, the total rentable building area in shadow and non-shadow areas during our sample period.\textsuperscript{13} Some of the results of this article could have arisen artificially if the post-9/11 period happened to coincide with a larger increase in the supply of office space in shadow

\textsuperscript{11} Notice that we do not fail to reject significance of the coefficients in Table V because of a large loss of statistical power relative to Table II. In fact, the standard errors are very similar in both tables. The coefficients of Table V, however, are small relative to the corresponding coefficients in Table II.

\textsuperscript{12} In particular, this test is robust to the presence of spatial correlation between the regression errors.

\textsuperscript{13} We computed total rentable areas for shadow and non-shadow areas using the all the office buildings in the CoStar database of Class A and Class B office buildings in the extended Chicago downtown area (as defined above).
areas than in non-shadow areas. On the contrary, Figure IV shows that in the post-9/11 period non-shadow areas experienced a higher increase in total rentable building area than shadow areas.

5. Conclusion

The results of this study suggest that the 9/11 attacks created centrifugal forces that influenced the location decision of high-end office tenants in downtown Chicago. We use the panel data structure of our dataset to eliminate the potential confounding effects that unmeasured building characteristics and common shocks to the Chicago office real estate market may have had in our analysis. We show that vacancy rates increased in Class A and B office buildings in Chicago after the 9/11 attacks. Moreover, we show that these decreases were more severe for office properties located in or nearby landmark buildings that are considered preferred targets for terrorist attacks. In addition, we demonstrate that our results are remarkably robust to an extensive set of alternative specifications.

The results of this article are particularly unsettling, given the critical role that the economic literature assigns to agglomeration economies in cities as a motor of economic growth.
Appendix: Building Class Definitions in the CoStar Database

**Class A:** A classification used to describe buildings that generally qualify as extremely desirable investment-grade properties and command the highest rents or sale prices compared to other buildings in the same market. Such buildings are well located and provide efficient tenant layouts as well as high quality, and in some buildings, one-of-a-kind floor plans. They can be an architectural or historical landmark designed by prominent architects. These buildings contain a modern mechanical system, and have above-average maintenance and management as well as the best quality materials and workmanship in their trim and interior fittings. They are generally the most attractive and eagerly sought by investors willing to pay a premium for quality.

**Class B:** A classification used to describe buildings that generally qualify as a more speculative investment, and as such, command lower rents or sale prices compared to Class A properties. Such buildings offer utilitarian space without special attractions, and have ordinary design, if new or fairly new; good to excellent design if an older non-landmark building. These buildings typically have average to good maintenance, management and tenants. They are less appealing to tenants than Class A properties, and may be deficient in a number of respects including floor plans, condition and facilities. They lack prestige and must depend chiefly on a lower price to attract tenants and investors.

**Class C:** A classification used to describe buildings that generally qualify as no-frills, older buildings that offer basic space and command lower rents or sale prices compared to other buildings in the same market. Such buildings typically have below-average maintenance and management, and could have mixed or low tenant prestige, inferior elevators, and/or mechanical/electrical systems. These buildings lack prestige and must depend chiefly on a lower price to attract tenants and investors.
FIGURE I

Chicago’s Central Business District Office Buildings and Shadow Areas

Crosses represent all Class A and Class B office buildings in Chicago’s Central Business District. Shaded circles represent 0.3-mile radius “shadow areas” surrounding the three main Chicago landmark buildings: the Aon Center, the Hancock Center, and the Sears Tower.
FIGURE II
Average Vacancy Rates in Shadow and Non-shadow Areas
FIGURE III
Permutation Distributions and p-Values
FIGURE IV
Total Rentable Areas in Shadow and Non-shadow Areas
### TABLE I

**DESCRIPTIVE STATISTICS – MEANS AND STANDARD DEVIATIONS**
(Class A and B office buildings in downtown Chicago)

<table>
<thead>
<tr>
<th>Characteristics of the buildings:</th>
<th>(1) Entire sample</th>
<th>(2) Inside shadow areas</th>
<th>(3) Outside shadow areas</th>
<th>(4) Diff. (2)-(3) (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>shadow (= 1 if in shadow area, = 0 otherwise)</td>
<td>.27 [0.45]</td>
<td>.44 [0.50]</td>
<td>.13 [0.34]</td>
<td>.31** [0.07]</td>
</tr>
<tr>
<td>Class A (=1 if Class A building, =0 if Class B building)</td>
<td>.21 [0.41]</td>
<td>.44 [0.50]</td>
<td>.13 [0.34]</td>
<td>.31** [0.07]</td>
</tr>
<tr>
<td>distance to anchor (miles)</td>
<td>.46 [0.26]</td>
<td>.19 [0.08]</td>
<td>.56 [0.24]</td>
<td>-.38** [0.02]</td>
</tr>
<tr>
<td>height (hundred feet)</td>
<td>2.76 [2.46]</td>
<td>4.43 [2.90]</td>
<td>2.14 [1.94]</td>
<td>2.29** [0.39]</td>
</tr>
<tr>
<td>rentable building area (sq. feet)</td>
<td>353,683 [499,847]</td>
<td>665,705 [604,842]</td>
<td>236,675 [397,123]</td>
<td>429,031** [80,243]</td>
</tr>
<tr>
<td>Vacancy rates (fraction):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First quarter of 2001</td>
<td>.0803 [0.0949]</td>
<td>.0901 [0.0903]</td>
<td>.0699 [0.0989]</td>
<td>.0202 [0.0174]</td>
</tr>
<tr>
<td>First quarter of 2006</td>
<td>.1491 [0.1306]</td>
<td>.1740 [0.1302]</td>
<td>.1228 [0.1266]</td>
<td>.0512** [0.0248]</td>
</tr>
<tr>
<td>Rent per square foot (current USD):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of buildings in the sample</td>
<td>242</td>
<td>66</td>
<td>176</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* Columns (1) to (3) report sample means, with the standard deviations in brackets. Column (4) reports the difference between columns (2) and (3), along with the standard deviation for the difference in parentheses. The sample is a balanced panel of Class A and Class B office buildings in the extended Chicago Central Business District between the second quarter of 1996 and the second quarter of 2006. See text of the article for the exact limits of the area of the City of Chicago included in our sample. Vacancy rates and rents are weighted by the rentable area of the buildings. Rent figures reflect asking rents for office building space available at the time of the survey. Data on rents for the first quarter of 2001 are available for 54 buildings inside the shadow areas and 80 buildings outside the shadow areas. Data on rents for the first quarter of 2006 are available for 55 buildings inside the shadow areas and 97 buildings outside the shadow areas.

* indicates statistical significance at the 10% level.

** indicates statistical significance at the 5% level.
### TABLE II

9/11 AND VACANCY RATES IN DOWNTOWN CHICAGO OFFICE BUILDINGS
(Fixed-effects estimates with clustered standard errors, 1996-2006)

<table>
<thead>
<tr>
<th>Dependent variable: Building vacancy rate</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>shadow area×post-9/11</td>
<td>.0303*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0166)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to anchor×post-9/11</td>
<td></td>
<td>-.0617*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0362)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to non-shadow area×post-9/11</td>
<td></td>
<td></td>
<td>.2302**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0633)</td>
<td></td>
</tr>
<tr>
<td>height×post-9/11</td>
<td></td>
<td></td>
<td></td>
<td>.0052**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(.0022)</td>
</tr>
</tbody>
</table>

| R-squared | .39 | .39 | .39 | .39 |
| Number of observations | 9,922 | 9,922 | 9,922 | 9,922 |

Note: The sample is a quarterly panel of Class A and Class B office buildings in the extended Chicago Central Business District between the second quarter of 1996 and the second quarter of 2006. See text of the article for the exact limits of the area of the City of Chicago included in our sample. Observations are weighted by the rentable area of the buildings. All specifications include building fixed effects and a full set of year×quarter dummies. Standard errors (in parentheses) are clustered at the building level.

* indicates statistical significance at the 10% level.

** indicates statistical significance at the 5% level.
### Table III

**Time Since 9/11 and Vacancy Rates in Downtown Chicago Office Buildings**

(Fixed-effects estimates with clustered standard errors, 1996-2006)

<table>
<thead>
<tr>
<th>Dependent variable: Building vacancy rate</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>shadow area×post-9/11</td>
<td>-.0046</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0173)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shadow area×quarters since 9/11</td>
<td></td>
<td>.0037**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to anchor×post-9/11</td>
<td></td>
<td>.0156</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0379)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to anchor×quarters since 9/11</td>
<td></td>
<td>-.0081**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0039)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to non-shadow area×post-9/11</td>
<td></td>
<td>.0614</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0639)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to non-shadow area×quarters</td>
<td></td>
<td>.0178**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>since 9/11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(.0060)</td>
</tr>
<tr>
<td>height×post-9/11</td>
<td></td>
<td></td>
<td>-.0003</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0022)</td>
<td></td>
</tr>
<tr>
<td>height×quarters since 9/11</td>
<td></td>
<td></td>
<td>.0006**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0002)</td>
<td></td>
</tr>
</tbody>
</table>

**R-squared**

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.39</td>
<td>.39</td>
<td>.39</td>
<td>.39</td>
</tr>
</tbody>
</table>

**Number of observations**

| 9,922 | 9,922 | 9,922 | 9,922 |

*Note:* The sample is a quarterly panel of Class A and Class B office buildings in the extended Chicago Central Business District between the second quarter of 1996 and the second quarter of 2006. See text of the article for the exact limits of the area of the City of Chicago included in our sample. Observations are weighted by the rentable area of the buildings. All specifications include building fixed effects and a full set of year×quarter dummies. Standard errors (in parentheses) are clustered at the building level.

* indicates statistical significance at the 10% level.

** indicates statistical significance at the 5% level.
<table>
<thead>
<tr>
<th>Post-9/11 Exposure to Terrorism</th>
<th>shadow area</th>
<th>distance to anchor</th>
<th>distance to non-shadow area</th>
<th>height</th>
</tr>
</thead>
<tbody>
<tr>
<td>exposure×year 2002</td>
<td>.0048</td>
<td>-.0125</td>
<td>.0966*</td>
<td>.0025</td>
</tr>
<tr>
<td></td>
<td>(.0143)</td>
<td>(.0287)</td>
<td>(.0579)</td>
<td>(.0016)</td>
</tr>
<tr>
<td>exposure×year 2003</td>
<td>.0118</td>
<td>-.0153</td>
<td>.1602**</td>
<td>.0030</td>
</tr>
<tr>
<td></td>
<td>(.0175)</td>
<td>(.0428)</td>
<td>(.0688)</td>
<td>(.0026)</td>
</tr>
<tr>
<td>exposure×year 2004</td>
<td>.0354*</td>
<td>-.0677</td>
<td>.2570**</td>
<td>.0033</td>
</tr>
<tr>
<td></td>
<td>(.0208)</td>
<td>(.0463)</td>
<td>(.0799)</td>
<td>(.0030)</td>
</tr>
<tr>
<td>exposure×year 2005</td>
<td>.0652**</td>
<td>-.1360**</td>
<td>.3791**</td>
<td>.0091**</td>
</tr>
<tr>
<td></td>
<td>(.0251)</td>
<td>(.0542)</td>
<td>(.0910)</td>
<td>(.0032)</td>
</tr>
<tr>
<td>exposure×year 2006</td>
<td>.0387</td>
<td>-.0924*</td>
<td>.2858**</td>
<td>.0114**</td>
</tr>
<tr>
<td></td>
<td>(.0246)</td>
<td>(.0560)</td>
<td>(.1027)</td>
<td>(.0036)</td>
</tr>
</tbody>
</table>

| R-squared                      | .39         | .39                | .39                         | .39   |
| Number of observations         | 9,922       | 9,922              | 9,922                       | 9,922 |

Note: The sample is a quarterly panel of Class A and Class B office buildings in the extended Chicago Central Business District between the second quarter of 1996 and the second quarter of 2006. See text of the article for the exact limits of the area of the City of Chicago included in our sample. Observations are weighted by the rentable area of the buildings. All specifications include building fixed effects and a full set of year×quarter dummies. Standard errors (in parentheses) are clustered at the building level. * indicates statistical significance at the 10% level. ** indicates statistical significance at the 5% level.
### TABLE V

**REGRESSIONS USING PRE-9/11 DATA ONLY**

(Fixed-effects estimates with clustered standard errors, 1996-2001)

<table>
<thead>
<tr>
<th>Dependent variable: Building vacancy rate</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>shadow area×after 1998</td>
<td>0.0120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0165)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to anchor×after 1998</td>
<td></td>
<td>-0.0313</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0370)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to non-shadow area×after 1998</td>
<td></td>
<td></td>
<td>0.1017</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0839)</td>
<td></td>
</tr>
<tr>
<td>height×after 1998</td>
<td></td>
<td></td>
<td></td>
<td>0.0026</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(.0025)</td>
</tr>
<tr>
<td><em>R-squared</em></td>
<td>.48</td>
<td>.48</td>
<td>.48</td>
<td>.48</td>
</tr>
<tr>
<td><em>Number of observations</em></td>
<td>5,324</td>
<td>5,324</td>
<td>5,324</td>
<td>5,324</td>
</tr>
</tbody>
</table>

*Note:* The sample is a quarterly panel of Class A and Class B office buildings in the extended Chicago Central Business District between the second quarter of 1996 and the third quarter of 2001. See text of the article for the exact limits of the area of the City of Chicago included in our sample. Observations are weighted by the rentable area of the buildings. All specifications include building fixed effects and a full set of year×quarter dummies. Standard errors (in parentheses) are clustered at the building level. * indicates statistical significance at the 10% level. ** indicates statistical significance at the 5% level.
References


