Commercial Office Space: Tests of a Real Options Model with Competitive Interactions

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Abstract

We test a real options model with competitive interactions using an extensive commercial real estate data base. The competitive nature of the local real estate market is proxied by a Herfindahl ratio characterizing competition amongst local developers. Consistent with Grenadier (2002, 2003), competition has a significant effect on commercial real estate development by interacting with volatility to attenuate the value of the developer’s option to wait. However, volatility also plays an important role independent of its interaction with competition.

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1 Introduction

There are many applications of real option pricing models to investment decision making in commercial real estate. Examples include, among others, Titman (1985), Williams (1991, 1993), and Quigg (1993). However, by treating the exercise price as exogenously given, traditional real option pricing models cannot take into account the fact that the exercise of the option (“investment”) by one developer may affect the building price faced by other developers and so influence their exercise strategy. Recently, however, researchers have begun to systematically investigate the effects of one developer’s exercise of this option on the investment decisions of others. In particular, Grenadier (2003) has developed a model to value real estate leases which explicitly takes these competitive interactions into account.

This paper takes advantage of an extensive commercial real estate data base to empirically investigate Grenadier’s real option pricing model with competitive interactions. Unfortunately, many of the assumptions needed to develop this model do not hold in practice. Therefore, rather than test the model per se, we empirically investigate the implications of the model for commercial real estate development. We focus on the model’s implications for the optimal exercise of the option to develop additional office space and investigate the effects of various explanatory variables posited by the model, including the degree of competition, on the trigger point at which such development occurs. Movements in the trigger point are proxied by the number of buildings starts, with a greater number of building starts corresponding to a lower trigger point. We then statistically test whether these variables do indeed influence the observed number of building starts in the direction posited by the model.

We present empirical results consistent with the observed number of building starts being systematically affected by many of the variables identified by Grenadier’s real option pricing model. In particular, the competitive nature of the local real estate market as proxied by a Herfindahl ratio characterizing competition amongst local developers significantly effects the number of building starts but only to the extent that this measure of competition interacts with volatility. That is, for a given in-
crease in volatility, more competition amongst local developers, as measured by a correspondingly lower Herfindahl ratio, results in a greater number of building starts or equivalently a lower trigger point at which the option to develop is exercised. However, volatility affects the number of building starts even after controlling for its interaction with competition. This suggests that volatility influences building starts for reasons other than simply determining the value of a developer’s option to wait.

Ours is not the only paper investigating the effects of competition on real option values in real estate. Bulan, Mayer and Sommerville (2002) examine condominium development in Vancouver, Canada between 1979 and 1998 and find that increases in risk, both systematic as well as unsystematic, delay condominium investment. They also find that an increase in competition, measured by the actual number of future developments that will be built nearby, attenuates this relation. Our papers differ in more than simply how the degree of competition prevailing in a particular market is measured. For example, Bulan, Mayer, and Sommerville look at only one market but over a longer period of time. We, by contrast, consider a number of different markets over time and so can exploit these cross-sectional differences to test the implications of the real option pricing model.

The plan of this paper is as follows. Section 2 reviews Grenadier’s model and summarizes the comparative statics of the trigger level at which investment will occur with respect to the model’s variables. Section 3 discusses our data and details the dependent and independent variables used to test Grenadier’s model. Section 4 puts forward our empirical methodology and discusses the empirical results. We conclude in Section 5.

2 Grenadier’s Model and Its Comparative Statics

In this section we briefly overview Grenadier’s real option pricing model (2002, 2003) with competitive interactions applied to commercial real estate. We focus on the model’s comparative statics which form the basis of our subsequent empirical analysis.
A local real estate market is assumed to be oligopolistic and made up of \( n \) identical developers who develop and lease identical buildings. To fix matters, at time \( t \), developer \( i \) owns \( q_i(t) \) units of completed and rentable space. The space is assumed to be infinitely divisible and the analysis is couched in a continuous time framework. At any point in time, developers can develop new rentable units at a constant cost of \( K \) per unit of space. This investment decision is assumed to be irreversible.

The value of owning a building arises from its underlying service flow. The instantaneous lease rate, \( P(t) \), is the price of the flow of these services. It is assumed that the lease rate evolves in such a way as to clear this market at each point in time. Following Dixit and Pindyck (1987), the market inverse demand function is assumed given by:

\[
P(t) = X(t)Q(t)^{-\frac{1}{\gamma}}
\]  

where the price elasticity of demand, \( \gamma \), satisfies\(^1 \) \( \gamma > \frac{1}{n} \) and \( Q(t) = \sum_{j=1}^{n} q_j(t) \) is the industry supply process. Here \( X(t) \) represents a multiplicative demand shock. Examples of demand shocks include, among others, changes in job growth, changes in industrial production, and changes in disposable income. The demand shock itself evolves as a geometric Brownian motion:

\[
dX(t) = \alpha X(t) dt + \sigma X(t) dZ
\]  

where \( \alpha \) is the instantaneous conditional expected percentage change in \( X(t) \) and \( \sigma \) is the instantaneous conditional standard deviation. The risk-free interest rate \( r \) is assumed to be constant with \( r > \alpha \) to ensure convergence. The cash flows are valued in a risk-neutral framework. That is, the process for \( X(t) \) is assumed to be risk-adjusted.

Given the above assumptions, Grenadier derives the corresponding symmetric Nash equilibrium development strategy. In particular, he obtains the equilibrium value of

\(^1\) Necessary to ensure a well-defined equilibrium. See Grenadier (2003).
each identical firm in closed-form:

\[ G(X, Q) = \frac{XQ^{\frac{\gamma-1}{n}}}{n(r - \alpha)} + B(Q)X^\beta \]  

where

\[ \beta = \frac{-(\alpha - \frac{1}{2}\sigma^2) + \sqrt{(\alpha - \frac{1}{2}\sigma^2)^2 + 2r\sigma^2}}{\sigma^2} > 1 \]

\[ B(Q) = \left( \frac{v_n^{-\beta}}{n} \right) \left( \frac{\gamma}{\gamma - \beta} \right) [K - \left( \frac{v_n}{r - \alpha} \right) \left( \frac{\gamma - 1}{\gamma} \right)]Q^{-\frac{\beta}{\gamma}} \]

\[ v_n = \left( \frac{\beta}{\beta - 1} \right) \left( \frac{n\gamma}{n\gamma - 1} \right)(r - \alpha)K \]

\[ X^*(Q) = v_nQ^{\frac{1}{\gamma}}. \]

The first term in equation (3) represents the present value of the growing perpetuity of cash flows generated by the commercial real estate assets in place. The second term, by contrast, gives the value of the option to develop additional space.

The equilibrium strategy for each developer is to develop an incremental unit whenever the state variable \( X(t) \) rises to the trigger level \( X^*(Q(t)) \). This solution implies that the equilibrium lease rate also follows a geometric Brownian motion but with an upper reflecting barrier at \( v_n \):

\[ dP(t) = \alpha P(t)dt + \sigma P(t)dZ \quad \text{when } P(t) < v_n \]  

\[ dP(t) = 0 \quad \text{when } P(t) = v_n. \]  

In other words, so long as \( X \) is sufficiently low, there will be no new investment and lease rates will evolve according to expression (4). Otherwise, the lease rate will be fixed, expression (5), and developers will invest.

Grenadier’s model is sufficiently rich in its implications regarding commercial real estate investment to allow us to explore the role of various economic variables in the decision to develop additional office space. In particular, the model’s implications with respect to the trigger level \( X^* \) at which additional investment occurs can be derived in a straight forward fashion.

Significantly, the trigger level is a decreasing and convex function in \( n \), the number
of developers:

\[
\frac{\partial X^*(Q)}{\partial n} = \frac{-X^*(Q)}{n(n\gamma - 1)} < 0
\]  
(6)

\[
\frac{\partial^2 X^*(Q)}{\partial n^2} = \frac{2\gamma X^*(Q)}{n(n\gamma - 1)^2} > 0.
\]

As a result, increasing competition leads developers to develop sooner as the fear of preemption diminishes the value of their “option to wait”.

The trigger level is a decreasing function of \(\alpha\), the expected rate of growth in the level of demand:

\[
\frac{\partial X^*(Q)}{\partial \alpha} < 0.
\]  
(7)

In other words, when demand is growing faster, all else being equal, the developer invests sooner.

The trigger level can also be seen to be an increasing function of the volatility of the demand shock \(X(t)\):

\[
\frac{\partial X^*(Q)}{\partial \sigma^2} > 0.
\]  
(8)

As in all option models without competitive interactions, an increase in volatility delays the point at which an American option is exercised. Here, however, this effect is attenuated by the presence of competitors:

\[
\frac{\partial}{\partial n}\left(\frac{\partial X^*(Q)}{\partial \sigma^2}\right) < 0.
\]  
(9)

That is, as the number of competitors \(n\) increases, investment delays in Grenadier's model are unambiguously reduced.

The trigger level is also an increasing function of the prevailing rate of interest\(^2\), that

\(^2\)This and the previous two comparative statics results are not general results, but hold for reasonable values of the model parameters.
When interest rates rise, the value of the option and the exercise trigger also increase. Of course, it should be pointed out that the model assumes constant interest rates as well as a flat term structure of interest rates.

Finally, the trigger function is increasing in $Q$:

$$\frac{\partial X^*(Q)}{\partial Q} > 0.$$  \hspace{1cm} (11)

As expected, all else being equal, the larger the existing supply of office space, the higher the trigger level.

2.1 Caveats

While Grenadier’s model is indeed rich in its implications for commercial real estate investment, it is nonetheless a highly simplified description of actual markets. For example, the model assumes that at each point in time the supply of office space equals its demand, with the lease rate equilibrating supply with demand. This implies an absence of vacancies in the model, yet in reality vacancies are observed with some degree of regularity. Actual vacancies reflect the time required to search for new office space and the transaction costs incurred in moving from one location to another, factors not explicitly addressed in Grenadier’s model. In addition, actual lease rates have been observed to be somewhat sticky and not adjusting quickly to changing market conditions.

This continuous time model also assumes that construction is instantaneous and that it can be accomplished in infinitesimal amounts. In reality there are construction lags which suggests that lagged values of the explanatory variables may affect current construction. Also, real estate investment is lumpy and so we can expect the empirical fit of the model to be far from perfect. In addition, the model assumes that developers are homogeneous and identical in all respects including constructing identical
buildings, thereby allowing a symmetric Nash equilibrium solution. However, actual developers vary in many respects including, among others, their size, efficiency, and preferences for particular building types.

In fact, Novy-Marx (2002) argues that Grenadier’s conclusion that competition erodes real option values and reduces investment delays rests critically on his assumption that developers are homogeneous and can add capacity in arbitrarily small amounts without incurring adjustment costs. To make his point, Novy-Marx provides a model of an industry with a large number of competitive firms in which opportunity costs as well as variable costs are incurred when altering capacity. As a result, real option values become significant, investment decisions are delayed, and investment will be lumpy. The implication for commercial real estate investment is that even though a large number of firms may compete vigorously, underlying heterogeneity prevents them from all competing directly over any given investment opportunity.

3 Data

Our data source is the CoStar Office Report which is derived from a data base maintained by the CoStar Group of existing and under construction office buildings in a number of U.S. metropolitan areas. It covers both single-tenant as well as multi-tenant buildings and includes office, office condominium, office loft, and office medical buildings, encompassing approximately 22 billion square feet of space in over 800,000 properties. The data are available on a quarterly basis and are compiled separately for class A versus class B versus class C buildings. According to CoStar, Class A buildings are extremely desirable investment-grade properties that command the highest rents or sale prices in a particular market. Class B buildings, by contrast, are less appealing and are generally deficient in floor plans, condition, and facilities. Class C buildings are older buildings that offer basic services and rely on lower rents to attract tenants.

We restrict our empirical analysis to class A and B buildings. As class C buildings tend to be older buildings, we observe little new construction activity for class C
buildings in the CoStar Office Report. For example, the median number of class C building starts in our sample is zero per quarter.

While our sample concludes with the second quarter of 2002, CoStar’s coverage begins at different times in different metropolitan areas. For the following thirteen metropolitan areas, data are available from at least the third quarter of 1998: Atlanta, Baltimore, Boston, Chicago, Dallas-Fort Worth, Los Angeles, Northern New Jersey, Orange County (CA), New York City, Philadelphia, San Francisco, Washington D.C., and Westchester County/Southern Connecticut. Data are available from the first quarter of 2000 for the following fifteen metropolitan areas: Charlotte, Cincinnati, Cleveland, Columbus, Denver, Detroit, Houston, Orlando, Phoenix, Sacramento, St. Louis, San Diego, Seattle, South Florida, and Tampa. Our sample will be restricted to these twenty-eight metropolitan areas. Data are available only after the first quarter of 2000 for the remaining metropolitan areas included in the CoStar Office Report and we exclude them from our analysis because of the limited number of observations.

3.1 Description of Variables

Grenadier’s model has implications for the valuation of office buildings as well as for the optimal exercise of the option to develop additional office space. In our empirical analysis we concentrate on the latter. That is, we investigate the effects of explanatory variables suggested by the model on the trigger point at which additional office space should be developed. For example, if the trigger point increases in response to, say, an increase in the value of a particular explanatory variable, we should observe less development then when the value of this variable is lower. In other words, we proxy movements in the trigger point by the number of buildings started, with a lower trigger point corresponding to a greater number of buildings starts.

We now turn our attention to the variables, both independent as well as dependent, relied upon in our subsequent empirical analysis. Their corresponding sample statistics are provided in Table 1.
3.1.1 Dependent Variable

The dependent variable is the number of buildings started during a quarter in a particular metropolitan area. Unfortunately, this information is not directly tabulated in the CoStar Office Report. It can, however, be determined from data available on the number of buildings delivered and the number of buildings under construction. In particular, the number of starts can be defined as the change in the number of buildings under construction plus the number of buildings delivered.\(^3\)

From Table 1 we see that the average number of class A building starts per quarter in a sampled metropolitan area is 4.90 with a median of 3 starts. The number of class B building starts is slightly higher with an average of 7.58 and a median of 4 starts. Since the number of building starts can only take on non-negative values, the minimum number of starts observed is zero. The maximum number of class A buildings starts is 37 in San Francisco during the first quarter of 2000 and a maximum of 94 class B building starts in Phoenix during the fourth quarter of 2000.

The number of building starts is a count variable. Being a count variable, there are numerous instances when we observe either zero or a very few starts per quarter; for example, over fifty percent of our sample of class A building starts involves no more than two starts per quarter. By contrast, there are only a few instances where we observe very many starts during a quarter. These features of count variables can be seen in Figure 1 where we provide histograms of the observed number of class A and B building starts, respectively.

3.1.2 Independent Variables

The explanatory variables are chosen to correspond to variables suggested by Grenadier’s model. We also include other explanatory variables in an attempt to address some of the previously discussed limitations of the model.

1. Herfindahl ratio: As of the end of our sample, the second quarter of 2002, the CoStar Office Report provides for each metropolitan area data on the area’s ten

\(^3\)An obvious deficiency of this measure is that it treats all buildings as having the same size.
largest developers ranked by the square footage of commercial real estate they
developed in the preceding twelve months. These data are not disaggregated by
building class as developers are not restricted to developing just one particular
class of buildings. To measure the degree of competition prevailing in each
region, we calculate a Herfindahl ratio defined as the sum of the squares of the
market shares developed by each of the top five developers.\footnote{Since the
market shares of the remaining five developers in a particular metropolitan area
tend to be rather small, our empirical results are unaffected if alternatively we
rely on a Herfindahl ratio based on all ten developers.} The larger this
ratio, the less competitive the market. We use this variable to proxy for the
level of competition, which in Grenadier’s model is represented simply by the
number of competitors. More competition leads to more investment and so we
expect the coefficient on the Herfindahl ratio in a regression of new building
starts to be negative.\footnote{It can be argued that by construction the Herfindahl
ratio is negatively correlated with the observed number of building starts. To see
this, note that in the extreme, if there is only one building started by a single
developer then the value of the Herfindahl ratio will be large (one) while the
observed number of building starts will be small. However, in our case, this
spurious link is substantially reduced if not eliminated. Firstly, the Herfindahl
ratio is based only on construction activity for the twelve month period ending in
the second quarter of 2002 but is used to explain building starts extending back
to the third quarter of 1998. Second, the Herfindahl ratio is based on
construction activity across all building classes but is used to separately explain
only class A building starts or only class B building starts.}

From Table 1 we see that the calculated Herfindahl ratios range from a low of
0.01 in Orlando, consistent with it being the most competitive market in our
sample, to a high of 0.18 in Tampa, the least competitive market.

2. **Growth of the lease rate:** For each metropolitan area, CoStar maintains time
series data on the corresponding quoted lease rates of class A and B buildings.
The growth rate of the percentage change in the observed lease rates is calculated
and used as a proxy for the demand shock’s growth rate. Being a proxy for the
drift of the demand shock process, we expect that the coefficient on the growth
rate in a regression of new building starts to be positive. From Table 1, the
average annualized growth rate in class A lease rates is 5% but varies from a low
of -1% in New York City to a high of 11% in Orlando. Class B lease rates grew
slower over our sample period, averaging only 2% with a low once again of -1%
in New York City and a high of 4% in Dallas-Fort Worth.

3. **Volatility of the lease rate:** The volatility of the percentage change in these
lease rates from one quarter to the next is calculated and used as a proxy for the volatility of the demand shock process. This variable is consistent with Grenadier’s model save for the fact that in the model the lease rate is subject to a reflecting barrier corresponding to the case where development occurs. This may, as a result, introduce a downward bias to our volatility estimate. However, in practice there does not exist a fixed boundary at which development occurs, so this bias should be minimal. As this is an option based model, increases in volatility will delay investment and so we expect that the coefficient on volatility in a regression of new building starts to be negative.

For our sampled metropolitan areas, the mean annualized volatility of class A lease rates is 8% with a median of 7%, while the mean annualized volatility of class B lease rates is 7% with a median of 6%. The minimum annualized volatility of class A lease rates is 3% in Cincinnati while San Francisco has the highest annualized volatility of class A lease rates of 18%. For class B lease rates, the minimum volatility is 3% in South Florida with a maximum of 13% in Sacramento.

Of course, a central message of Grenadier’s model is that the degree of competition prevailing in a market should systematically influence the extent to which increases in volatility actually delay commercial real estate investment. In particular, the more competitive a market, that is, the smaller a metropolitan area’s Herfindahl ratio, the shorter the investment delay that should be observed for a given increase in volatility. This implies a negative coefficient in a regression of new building starts on a term interacting volatility with the Herfindahl ratio.

4. Treasury bond rate: At the beginning of each quarter, interest rate conditions are measured by prevailing Treasury bond rates. We rely primarily on the real ten year Treasury rate since commercial real estate development tends to be a longer lived investment. Real rates are obtained by deflating corresponding nominal rates using the previous quarter’s realized rate of inflation based on the Bureau of Labor Statistics’s Producer Price Index (PPI) for construction materials and components. From Grenadier’s model, we expect the coefficient
on the interest rate variable in a regression of new building starts to be negative.

5. Spread: The term spread, measured by the difference between the ten year and one year nominal Treasury yields, is also included. As well as providing an alternative measure of prevailing interest rate conditions, the term spread is a business cycle proxy and its inclusion allows us to investigate whether business cycle conditions influence office building starts. All interest rate data are obtained from Datastream.

6. Total Number of Buildings: For each metropolitan area, the CoStar Office Report provides data on the total inventory of class A and B buildings. Since metropolitan areas differ in size, we need to control for these differences which do not appear in Grenadier’s model. Of course, larger markets should experience more construction and so the coefficient on this variable in a regression of new building starts should be positive. According to the CoStar Office Report, Los Angeles is the largest market for both class A and B buildings. Orlando is the smallest market for class A buildings while Columbus is the smallest market for class B buildings.

7. Lagged vacancy rate: The vacancy rate variable is defined as the percentage of total vacant space for class A or B buildings divided by their total existing inventory. As noted earlier, contrary to Grenadier’s model, there are good reasons to expect vacancies to actually occur and their level to be negatively related to new building starts. We lag the vacancy rate to capture the fact that it typically takes time for new building starts to respond to changes in vacancy rates.

The mean vacancy rate for class A buildings is 13% with a median of 12%, being lowest (4%) in San Francisco during the first quarter of 2001 and highest (23%) in Phoenix during the second quarter of 2002. For class B buildings, the mean vacancy rate is 11% with a median of 12%. The minimum class B vacancy rate is 5% in Seattle during the third quarter of 2000 and the maximum is 20% in Dallas-Fort Worth during the third quarter of 2002.
4 Empirical Method and Results

4.1 Poisson Regression

A count variable only takes on nonnegative integer values. As noted earlier, the number of buildings started in a given quarter is a count variable. Like other count variables, there is no natural \textit{a priori} upper bound on the number of these buildings started and, at the other extreme, the outcome could very well be zero.

If $y$ denotes our count variable and $\mathbf{x}$ is a vector of explanatory variables, we are interested in estimating the population regression, $E(y|x)$. The most straightforward approach is a linear model, $E(y|x) = \beta \mathbf{x}$ and estimating the parameter vector $\beta$ using ordinary least squares (\textit{OLS}). Unfortunately, if $\hat{\beta}$ is the \textit{OLS} estimator, there can be values of $\mathbf{x}$ such that $\hat{\beta} \mathbf{x} < 0$, so that the predicted number of new buildings started will be negative, clearly inappropriate for count data.

Alternatively, we will use a Poisson regression model to analyze our count data. That is, $y$ given the covariates $\mathbf{x} \equiv (x_1, x_2, \ldots, x_k)$ is assumed to have a Poisson distribution whose density is

$$ f(y|\mathbf{x}) = \exp[-\mu(\mathbf{x})][\mu(\mathbf{x})]^y/y! \quad y = 0, 1, 2, \ldots $$

where $\mu(\mathbf{x})$ denotes the conditional mean $\mu(\mathbf{x}) \equiv E[y|x]$.

Assuming $\mu(\mathbf{x}) = \exp(\mathbf{x} \beta)$, which ensures positivity for any value of $\mathbf{x}$ and any parameter value, as well as a random sample $\{(\mathbf{x}_i, y_i) : i = 1, \ldots, n\}$, the log likelihood for observation $i$ is

$$ \ell_i(\beta) = y_i \log[\mu(\mathbf{x}_i; \beta)] - \mu(\mathbf{x}_i; \beta) = y_i \mathbf{x}_i \beta - \exp(\mathbf{x}_i \beta). \quad (13) $$

The parameters of this model are easy to interpret. Since

$$ \frac{\partial E(y|x)}{\partial x_j} = \exp(\mathbf{x} \beta) \beta_j $$
then

\[ \beta_j = \frac{\partial E(y|x)}{\partial x_j} \times \frac{1}{E(y|x)} \]

\[ = \frac{\partial \log [E(y|x)]}{\partial x_j}. \] (14)

That is, \(100\beta_j\) is the semi-elasticity of \(E(y|x)\) with respect to \(x_j\). That is, for small changes in \(x_j, \Delta x_j\), the percentage change in \(E(y|x)\) is approximately \(100\beta_j \times \Delta x_j\).

Unfortunately, the Poisson model implies the equality of the conditional mean and variance of \(y\):

\[ \text{var}(y|x) = E(y|x) \]

which is often violated in practice. We will make the weaker assumption that

\[ \text{var}(y|x) = \xi^2 E(y|x) \]

where \(\xi^2 > 0\) is the variance-mean ratio to be estimated.

Finally, if \(y_i\) given \(x_i\) is not Poisson distributed, then the estimator that maximizes the log likelihood function, expression (13), is a quasi-maximum likelihood estimator. Under mild regularity conditions, the quasi-maximum likelihood estimator retains a number of desirable properties.\(^6\)

4.2 Empirical Results

Table 2 presents our estimation results. For each regression specification, we present the estimated coefficients as well as asymptotic (in parentheses) and bootstrapped (in square brackets) \(p\)-values testing the null hypothesis that the corresponding coefficient equals zero. Bootstrapping\(^7\) ensures that our inference is valid for the sample

\(^6\)In particular, the quasi-maximum likelihood estimator is consistent and is efficient in the linear exponential family of distributions. For example, it is more efficient than the nonlinear least squares estimator. For further details, see Wooldridge (2002), especially Chapter 19, pages 645-683.

\(^7\)To do so, we sample with replacement from the original data series and estimate a particular model using Poisson regression. We repeat this procedure five hundred times to form an empirical distribution of each parameter of interest.
sizes typically encountered in practice and accommodates other deviations from the
maintained distributional assumptions that may be present in our data.

We also tabulate for each regression specification the estimated dispersion, \( \hat{\xi} \), and
assess fit using a pseudo \( R^2 \) statistic, calculated as the squared correlation between
the predicted and actual number of building starts.\(^8\) Overall, we fit class A building
starts better than class B building starts. We can explain over 50% of the observed
class A building starts as opposed to only 30% of the observed class B building starts.

Our first regression specification investigates for each building class whether individually competition and volatility affect the observed number of building starts. In each
case, competition and volatility can be seen to influence the number of building starts
in the direction posited by Grenadier’s model, although the increase in the number
of building starts associated with an increase in competition, that is, a decrease in
the Herfindahl ratio, is only statistically significant in the case of class B building
starts. Lease volatility plays a statistically significant role for both class A and B
building starts with an increase in lease volatility being associated with a decrease in
the number of starts.

However, higher volatility can delay building starts for reasons other than an increase
in the value of the option to wait. For example, if non-systematic risk is priced
then higher volatility decreases the value of a commercial real estate project and can
thereby delay its implementation. By contrast, in the real options approach, all else
being equal, the project’s value is enhanced by higher volatility and the delay in the
project’s implementation arises from the developer taking advantage of the resultant
increase in the option’s time value. Unfortunately, data on project values is unavail-
able and so cannot be relied upon to discriminate between these alternatives. To do
so, recall that an interaction term between volatility and competition should play a
significant role in the real options approach but not in the risk adjusted discounted
cash flow model. According to Grenadier’s model, volatility’s importance as a de-
terminant of building starts decreases with increasing competition. In the extreme,

\(^8\)Because this statistic does not mean what the \( R^2 \) statistic means in ordinary least squares (OLS) regression - the
proportion of variance explained by the posited regressors - it should be interpreted with caution.
volatility should have no impact whatsoever on the observed number of building 
starts if developers are perfectly competitive. Similarly, while there may be other 
economic arguments as to why a decrease in competition itself should delay building 
starts, Grenadier’s model asserts that competition only matters if volatility is high 
and developers fear the preemption of their now more valuable option to delay.

We next empirically investigate the interaction between volatility and competition 
for each building class. In particular, the second regression specification includes 
this interaction term together with the competition variable itself. Notice that the 
Herfindahl ratio is no longer significant even for explaining the number of class B 
building starts while the interaction term is statistically significant and is of the neg-
ative sign predicted by Grenadier’s model. In other words, consistent with Grenadier’s 
model, competition *per se* is not important but rather is only important to the extent 
that it interacts with volatility to attenuate the value of the option to wait.

The third regression specification includes the interaction term together with the 
volatility variable itself. Now the volatility variable is negative, significantly so for 
class B starts but only marginally significant for class A starts. However, the in-
teraction term, while being of the negative sign predicted by Grenadier’s model, is 
not statistically significant for either class of buildings. Our interpretation here is 
that volatility is an important determinant of building starts over and above how it 
interacts with the degree of competition prevailing in markets. This is in contrast to 
Grenadier’s model where the only channel through which volatility affects building 
starts is its influence on option value which interacts with competition. The fact 
that volatility remains a significant determinant of building starts in the presence of 
this interaction term suggests that volatility can influence building starts not only as 
hypothesized by Grenadier but also, for example, as predicted by a discounted cash 
flow model in which non-systematic risk is priced.

Regardless of the particular regression specification, a number of other patterns 
emerge from the results of Table 2. For example, we see that the larger the mar-
ket, as measured by the log of the total number of buildings, either class A or class B, 
the greater the number of corresponding building starts. The expected rate of growth
in demand proxied by the lease growth rate influences the number of building starts. The higher this growth rate, the larger the number of building starts.

Contrary to Grenadier’s model, however, we see across regression specifications and building classes that increases in the ten year real Treasury yield actually results in a significant increase in the number of building starts. The negative coefficient on the term spread across regression specifications and building classes implies that fewer building starts are observed when the term spread is wide. Recall that wide term spreads are typical of business cycle troughs. Conversely, narrow term spreads that characterize business cycle peaks are associated with more building starts.

Finally, as expected, we see that an increase in lagged vacancy rates tends to decrease the number of building starts. This effect is statistically significant in the case of class B building starts but not class A building starts.

5 Conclusion

Over the years, real options models have provided economists with a better understanding of investment decision making. Recently, researchers have began to investigate the role of competition in these models. Using an extensive commercial real estate data base, this paper empirically investigates the importance of competition in actual investment decision making. In particular, we find that the number of office building starts across twenty-eight U.S. metropolitan areas over the 1998 to 2002 sample period is indeed influenced by the competitive nature of the local real estate market. Consistent with Grenadier (2002, 2003), competition has a significant effect on commercial real estate development by interacting with volatility to attenuate the value of the developer’s option to wait. However, we find that volatility also plays an important role in determining the number of building starts independent of its interaction with competition.

Our results suggest that incorporating game theoretic concepts into real options models has the potential to improve our understanding of investment decision making in
markets other than commercial real estate. Empirical tests such as ours are important in identifying the deficiencies of current real options models and suggesting avenues for new research to improve their applicability. For example, while we have relied solely on the Herfindahl ratio to characterize competition in this paper, if the data is available, other measures of competition, such as that relied on by Bulan, Mayer, and Somerville (2002) should also be considered. Also, it would be interesting to further investigate the role of volatility in investment decision making with competitive interactions. While we have provided empirical evidence consistent with volatility influencing buildings starts beyond its interaction with competition, whether this result characterizes other markets awaits future research.
References


Table 1

Sample Statistics

This Table presents various sample statistics for the independent and dependent variables used in our empirical analysis. We separately provide statistics for the sample of class A buildings versus the sample of class B buildings. Our data are quarterly in frequency over the 1998:III to 2002:II sample period and include the following U.S. metropolitan areas: Atlanta (ATL), Baltimore (BAL), Boston (BOS), Charlotte (CHA), Chicago (CHI), Cincinnati (CIN), Cleveland (CLE), Columbus (COL), Dallas-Fort Worth (DFW), Denver (DEN), Detroit (DET), Houston (HOU), Los Angeles (LAX), Northern New Jersey (NNJ), New York City (NYC), Orange County (LAO), Orlando (ORL), Philadelphia (PHI), Phoenix (PHX), Sacramento (SAC), San Diego (SDO), San Francisco (SFO), Seattle (SEA), St. Louis (STL), South Florida (SFL), Tampa (TAM), Washington D.C. (WAS), and Westchester County/Southern Connecticut (WCT).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Std Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A class buildings:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Building Starts (per quarter)</td>
<td>4.90</td>
<td>3</td>
<td>5.83</td>
<td>0: numerous cities</td>
<td>37: SFO in 2000:1</td>
</tr>
<tr>
<td>Lease Growth Rate</td>
<td>0.05</td>
<td>0.05</td>
<td>0.03</td>
<td>-0.01: NYC</td>
<td>0.11: ORL</td>
</tr>
<tr>
<td>Vacancy Rate (Lagged)</td>
<td>0.13</td>
<td>0.12</td>
<td>0.03</td>
<td>0.04: SFO in 2001:1</td>
<td>0.23: PHX in 2002:2</td>
</tr>
<tr>
<td>Lease Volatility</td>
<td>0.08</td>
<td>0.07</td>
<td>0.04</td>
<td>0.03: CIN</td>
<td>0.18: SFO</td>
</tr>
<tr>
<td><strong>B class buildings:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Building Starts (per quarter)</td>
<td>7.58</td>
<td>4</td>
<td>10.82</td>
<td>0: numerous cities</td>
<td>94: PHX in 2000:1</td>
</tr>
<tr>
<td>Log Total Number of Buildings</td>
<td>7.13</td>
<td>7.23</td>
<td>0.56</td>
<td>5.94: COL in 2000:1</td>
<td>8.10: LAX in 2002:2</td>
</tr>
<tr>
<td>Lease Growth Rate</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.01: NYC</td>
<td>0.04: DFW</td>
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<tr>
<td>Vacancy Rate (Lagged)</td>
<td>0.11</td>
<td>0.12</td>
<td>0.03</td>
<td>0.05 SEA in 2000:3</td>
<td>0.20: DFW in 2002:2</td>
</tr>
<tr>
<td>Lease Volatility</td>
<td>0.07</td>
<td>0.06</td>
<td>0.03</td>
<td>0.03: SFL</td>
<td>0.13: SAC</td>
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<tr>
<td>Ten year real Treasury yield (per cent)</td>
<td>2.72</td>
<td>2.63</td>
<td>0.86</td>
<td>1.52</td>
<td>4.20</td>
</tr>
<tr>
<td>Spread (per cent)</td>
<td>1.06</td>
<td>0.83</td>
<td>1.32</td>
<td>-0.77</td>
<td>3.65</td>
</tr>
<tr>
<td>Herfindahl ratio</td>
<td>0.09</td>
<td>0.08</td>
<td>0.04</td>
<td>0.01: ORL</td>
<td>0.18: TAM</td>
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</tbody>
</table>
This Table presents the results of estimating Poisson regressions to explain the observed number of office building starts by various explanatory variables. The results are tabulated separately for A class buildings versus B class buildings. For each explanatory variable we provide its estimated regression coefficient together with asymptotic (in parentheses) and bootstrapped (in square brackets) $p$-values testing the null hypothesis that the coefficient equals zero. We also tabulate for each regression specification its estimated dispersion, $\hat{\xi}$, and its pseudo $R^2$ statistic, calculated as the squared correlation between the predicted and actual number of building starts. For each building class, the first regression specification investigates whether competition and volatility separately influence the observed number of starts, while the second and third specifications investigate whether competition and volatility, respectively, in conjunction with their interaction influences the observed number of starts.

### A class buildings:

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Herfindahl ratio</th>
<th>Lease growth rate</th>
<th>Lease volatility</th>
<th>Lease volatility $\times$ Herfindahl ratio</th>
<th>Ten year real T-bond rate</th>
<th>Term Spread</th>
<th>Total Number of Buildings</th>
<th>Lagged vacancy rate</th>
<th>$\hat{\xi}$</th>
<th>Pseudo $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5.552</td>
<td>-1.228</td>
<td>18.468</td>
<td>-1.995</td>
<td></td>
<td>0.543</td>
<td>-0.460</td>
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<td>-1.850</td>
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<td></td>
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<td></td>
<td>(0.203)</td>
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<td>-5.790</td>
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<tr>
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<td>(&lt; .01)</td>
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<td>(0.130)</td>
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### B class buildings:

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<tr>
<th>Intercept</th>
<th>Herfindahl ratio</th>
<th>Lease growth rate</th>
<th>Lease volatility</th>
<th>Lease volatility $\times$ Herfindahl ratio</th>
<th>Ten year real T-bond rate</th>
<th>Term Spread</th>
<th>Total Number of Buildings</th>
<th>Lagged vacancy rate</th>
<th>$\hat{\xi}$</th>
<th>Pseudo $R^2$</th>
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<tr>
<td>-1.793</td>
<td>2.850</td>
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<td>-3.026</td>
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<td>47.483</td>
<td>-59.777</td>
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<td>(0.046)</td>
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