Interest Rate and Investment under Uncertainty: Evidence from Commercial Real Estate Capital Improvements*

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Abstract

This paper empirically analyzes the non-monotonic influence that interest rate changes have on irreversible investment in income producing properties. Using the complete history of quarterly capital improvements for 1,416 commercial properties over the 1978 to 2009 period, we find strong evidence of the non-monotonic effect for apartment, office, and retail properties, but not for industrial properties. For the first three property types, a decrease in the Treasury yield dramatically increases capital improvements when property values are high, but has a weak or negative effect when property values are low. This result has important implications for monetary and fiscal policies.

JEL classification: E22, E52

Key words: interest rate, investment under uncertainty, commercial real estate

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I. Introduction

Investment under uncertainty is one of the most important economic decisions that investors make (e.g. Dixit and Pindyck (1994)). Among all variables that might affect investment, interest rate changes have important implications for monetary and fiscal policies, and have drawn a lot of attention from economists. While the neoclassical theory of investment (e.g. Jorgenson (1963)) predicts that a decrease in the interest rate increases investment by reducing the cost of capital, recent theoretical analyses (e.g. Capozza and Li (1994), Capozza and Li (2002), and Chetty (2007)) suggest that, when firms make irreversible investments with uncertain pay-offs, the effect of an interest rate change on investment is non-monotonic. Chetty (2007) specifically suggests that investment is a backward-bending function of the interest rate. This means that a decrease in the interest rate reduces investment when the interest rate is "low", in the sense that the difference between the interest rate and the expected future income growth rate is small, and increases investment when the interest rate is "high". While focusing on empirical analyses, Capozza and Li (2001) also show that the difference between the discount rate and the expected future income growth rate influences the investment responses to interest rate changes.

We empirically analyze the non-monotonic effect of interest rate changes on irreversible investment using a unique dataset of individual capital improvements of 1,416 large commercial properties, including apartment, office, industrial and retail properties, in a sample period from 1978 to 2009. In our empirical model, the non-monotonic effect is captured by an interaction term between the change in the interest rate and the capitalization rate of properties. The capitalization rate, which is also called the cap rate by real estate professionals, equals the ratio of net operating income (NOI) to the property value. Real estate professionals conventionally use the cap rate as a measurement of the valuation of properties: a low (high) cap rate indicates high (low) property valuation. We show that, under reasonable assumptions, the cap rate measures the difference between the cost of capital and the expected future income growth rate. Therefore, the theory by Chetty (2007) predicts that a decrease in the interest rate increases (reduces) the capital improvement when the cap rate is low (high).

We find strong evidence for the non-monotonic effect of interest rate changes on the capital improvements in apartment, office, and retail properties, but not for industrial properties. For the first three types of properties, a decrease in the Treasury yield dramatically increases expenditures on capital improvements when property values are high (low cap rates), but has little or negative effect when properties have low valuation (high cap rates). For example, when the cap rate is 4%, a decrease of 50 basis points in the Treasury yield increases the capital improvement by 18% for apartments, 15% for offices, and 31% for retail properties, but the same interest rate decrease has no or negative effect when the cap rate is 10%. This result indicates that a decrease in the interest rate may strongly stimulate investment in a booming economy when asset values are high, but will have no or negative effect on investment in a recession when assets values are low. This result has important policy implications. If a decrease in the interest rate does not necessarily stimulate investment, then monetary authorities should take extreme care when they try to use interest rate changes to stimulate investment.

The empirical evidence described above is novel. In fact, the existing literature provides little empirical evidence regarding the non-monotonic effect of interest rate changes on investment. The only empirical analysis prior to this paper is Capozza and Li (2001), which, however, differs from this paper in research questions, data, method, and findings. For example, Capozza and Li (2001) empirically analyze and substantiate the effect of the population growth rate and its uncertainty on the likelihood of positive investment response to interest rate changes, while we analyze and provide direct evidence that investment is a backward bending function of the interest rate. Overall, the finding in this paper that the investment effect of interest rate changes is related to asset valuation is original, has important policy implications, and makes an important contribution to the literature.

The novel empirical evidence in this paper is made possible by the unique and high quality dataset employed, which has a few important advantages. First, the real estate market is an ideal environment to analyze investment under uncertainty, since real estate investments, including capital improvements and development, are not only irreversible but also affected by real options (e.g. Williams (1997)). Second, the dataset contains accurate measurements of both the timing and the amount of capital improvements *at the property level* over the *entire investment period* of each property. Property level data, or firm level data in a non-real estate environment, are desirable for testing investment theories but are rarely available. Many researchers, including Guiso and Parigi (1999), argue that property or firm level data are superior to aggregate data in testing investment theories because investment decisions are made at the firm/property level.

Third, the sample period of the data is 30 years. This period covers several economic cycles and provides valuable opportunities to observe dramatic changes in interest rates, which makes the empirical tests in this paper powerful. Finally, the dataset contains accurate information on the net operating income and owners' appraised property values, which allows the calculation of the cap rate and thus facilitates the measurement of property owners' expectation of future income growth. While investors' expectation is an important variable that affects investment, it is rarely observed in empirical research, with Guiso and Parigi (1999) being a notable exception.

The rest of this paper is organized as follows. Section II reviews the literature. Section III discusses the empirical model. Section IV describes the data. Section V presents empirical results, and section VI concludes.

II. Literature review

Pindyck (1991), Dixit and Pindyck (1994), Trigeorgis (1996), and Schwartz and Trigeorgis (2001) provide good summaries of theoretical and empirical analyses on irreversible investment under uncertainty. Below we briefly review more recent literature, which focuses more on real option-based theories, the relationship between the cost of capital and investment, and the influence of market structure on investment.

On the theory side, recent contributions to this literature include Grenadier (2002), Wang and Zhou (2006), Novy-Marx (2007), and Chetty (2007). Grenadier (2002) demonstrates that competition reduces the value of an investor's real option and consequently increases investment. Novy-Marx (2007) shows that, even in competitive markets, as long as products and opportunity costs are heterogeneous, the option to delay can be valuable and thus investment can be lumpy. Wang and Zhou (2006) demonstrate that the value of real options depend on market structure (e.g. competitive, monopolistic, etc.). Chetty (2007) shows that a change in the interest rate affects not only the net present values (NPVs) of possible projects but also the value of waiting. More importantly, the effect on the value of waiting is stronger (weaker) than the effect on the NPVs when the interest rate is "low" ("high").[1] Therefore, a decrease in the interest rate reduces

[1] The "low" and "high" is defined according to the difference between the interest rate and the expected future income growth rate. An interest rate is "low" if the difference is small.

investment when the interest rate is low, but increases investment when the interest rate is high. This non-monotonic effect of interest rates on investment is the main hypothesis of this paper.

On the empirical side, many recent analyses focus on non-real estate industries. For example, Leahy and Whited (1996) use a panel of 772 manufacturing firms over the 1981 to 1987 period to examine the response of investment to uncertainty. They demonstrate that firms postpone investments when the uncertainty of the payoff increases. Guiso and Parigi (1999) use cross-sectional data for 549 Italian manufacturing firms to examine whether uncertainty in future expected benefits influences current investment. Their survey data provide a unique opportunity to observe, rather than estimate, managers' expectations of future expected benefits. They find strong evidence for the value of real options, and that uncertainty has a substantially stronger influence on investment in firms that cannot easily dispose of excess capital equipment in secondary markets. Moel and Tufano (2002) use a Probit model to examine the openings and closings of 285 mines over the 1988-1997 period. They conclude that the probability of opening depends on gold prices, volatility in gold prices, mining costs, and capital costs. Bloom, Bond and Reenen (2007) fit data for 672 publicly traded U.K. manufacturing companies over the 1972-1991 period to an Error Correction Model (ECM), which relates the investment of a firm to sales growth rates, cash flow, transformations of these variables and uncertainty in investment returns. They conclude that uncertainty reduces the responsiveness of investment to demand shocks.

Some important papers in the literature analyze real estate investments. Titman (1985), Quigg (1993) and Capozza and Li (1994) examine the option component of undeveloped land value. Capozza and Li (2001) and Bulan, Mayer and Somerville (2009) use option-based models to analyze residential property development. Holland, Ott and Riddiough (2000), Sivitanidou and Sivitanides (2000), Schwartz (2007), and Fu and Jennen (2009) use real options to analyze commercial property development. Below we briefly review these papers.

Titman (1985) uses option theory to value vacant land, and is arguably the first paper on real options. He argues that vacant land can have a variety of different end uses, each with its own market value. The uncertainty in how the vacant land will ultimately be used (and the corresponding rents those properties will generate) is best modeled using real options. Quigg (1993) estimates the real option value associated with real estate development using data on

2,700 land transactions in Seattle. She reports a mean option value premium (over intrinsic value) of 6%. Capozza and Li (1994) use real options to model the intensity and timing of capital intensive investment decisions (like real estate). They use an optimal stopping framework that incorporates the value, intensity and timing of the project.

Capozza and Li (2001) use annual data on single-family building permits in 56 metropolitan housing markets over the 1980 to 1989 period to analyze the relationship between interest rate changes and housing development. They report that the housing permit growth rate more likely positively responds to interest rate increases when the population growth rate and its volatility are higher. Bulan, Mayer and Somerville (2009) use data for 1,297 condominium transactions in Vancouver over the January 1979 through February 1998 period to analyze the effect of risk on condo development. They estimate a reduced form hazard model, and conclude that the probability of condo development is lower with greater idiosyncratic risk and greater market risk, and that competition significantly reduces the sensitivity of option exercise to volatility.

Holland, Ott and Riddiough (2000) provide empirical evidence that option-based investment models outperform neoclassical models in explaining commercial real estate new construction. They estimate a two equation model – one equation for property prices and a second for the stock of commercial real estate space – using quarterly national price indices over the 1972-1992 period from the National Council on Real Estate Investment Fiduciaries (NCREIF) and the National Association of Real Estate Investment Trusts (NAREIT). Sivitanidou and Sivitanides (2000) also empirically examine commercial property development. They analyze CB Richard Ellis/Torto Wheaton survey data for 15 metropolitan office property markets over the 1982 to 1998 period, and conclude that uncertainty in demand growth, increases in the real discount rate, and increases in construction costs reduce investment while rental income growth and expected demand growth increase investment.

Using quarterly CoStar data from 1998:3 to 2002:2 for 14 metropolitan office markets, Schwartz (2007) analyzes the determinants of the number of office building starts. They conclude that volatility in lease rates reduces building starts; more competition increases starts; and competition reduces the value of the developer's option to delay. Fu and Jennen (2009) examine office space new construction in Singapore and Hong Kong (semi-annual data beginning in 1980 for Singapore and annual data beginning in 1978 for Hong Kong). They conclude that market volatility reduces the influence that real interest rates and growth expectations have on office starts.

This paper has a key difference from existing empirical papers that analyze investment except Capozza and Li (2001): this paper focuses on the non-monotonic effect of interest rate changes on investment predicted by Chetty (2007) and Capozza and Li (2001). It is worth noting that while Capozza and Li (2001) and this paper both analyze non-monotonic effects of interest rate changes, the two papers use different data, methods, and most importantly report different findings. Further, the two empirical analyses are different. While Capozza and Li (2001) examine the effect of population growth rate and its volatility on the investment effect of interest rate changes, this paper analyzes the influence that interest rate changes have on real property capital investments.

This paper has other noticeable differences from all existing empirical papers that study real estate investment, including Capozza and Li (2001). First, the existing real estate investment papers analyze real estate *development*, while this paper is the first that analyzes *capital improvements*. Second, the dataset we use provides accurate measurement of the timing and the amount of investment, while existing empirical papers estimate investment timing and amount. Third, this paper analyzes investment at the property level, while all existing papers on real estate investment employ indirect investment measurements at aggregate levels. Finally, this paper uses property level cap rates to help capture *property owners'* expectation of future income growth, while existing papers assume that investors' expectation is affected by variables such as population growth etc.

III. Research Design

This paper uses a model that is similar with the ones in Guiso and Parigi (1999) and Bloom, Bond and Reenen (2007) to test the non-monotonic effect of interest rate changes on investment. We use "interest rates" and "discount rates" interchangeably thereafter, as the literature often does. We model the optimal capital investment of property i in period t, $Inv_{i,t}$, using the following process:

$$
\begin{aligned}
Inv_{i,t} = \alpha_i + \left(\rho_1 + \rho_2\left(Dis_{i,t} - Growth_{i,t}\right)\right)\Delta Dis_{i,t} + \rho_3 Growth_{i,t} \\
+\rho_4 Vol_{i,t} + \rho_5 Growth_{i,t} \times Vol_{i,t} + \rho_6 Phy_{i,t} + \rho_7 Buy_{i,t} + \rho_8 Sell_{i,t} + \varepsilon_{i,t}
\end{aligned}
\tag{1}
$$

In equation (1), α_i is a property specific intercept term; $Dis_{i,t}$ is the property owner's discount rate for future cash flows; $Growth_{i,t}$ is the expected growth rate of future income, which captures demand changes; $\Delta Dis_{i,t}$ is the change in the discount rate from period $t-1$ to t; $Vol_{i,t}$ measures the uncertainty of the expected income growth rate $Growth_{i,t}$; $Phy_{i,t}$ captures the physical condition of the property in period t; $Buy_{i,t}$ is a dummy variable that equals 1 if the property was acquired in quarter $t-1$; $Sell_{i,t}$ is a dummy variable if the property was sold in quarter $t+1$; $\varepsilon_{i,t}$ is an error term that captures all other variables that might affect the investment.

Equation (1) uses the interaction between the change in the discount rate, $\Delta Dis_{i,t}$, and the difference between the discount rate and the expected income growth rate, $Dis_{i,t} - Growth_{i,t}$, to capture the non-monotonic effect of interest rate changes on investment that is predicted by Chetty (2007) and Capozza and Li (2001). Both papers suggest that the effect of changes in the interest rate have on investment relates to the difference between the discount rate and expected future income growth. A statistically significant estimated coefficient for the interaction term, ρ_2, would provide empirical evidence of the non-monotonic influence that changes in interest rates have on investment.

Equation (1) includes a variety of factors that likely influence irreversible investment. First, the property specific intercept term helps capture investment needs associated with unobserved time invariant property attributes, such as property type, location, etc. Second, theory predicts that investment responds positively to increases in the expected income growth rate $Growth_{i,t}$, so $Growth_{i,t}$ is expected to have a positive coefficient. Third, investment is expected to negatively react to the uncertainty in the expected income growth rate $Vol_{i,t}$. Consequently, $Vol_{i,t}$ is expected to have a negative coefficient. Fourth, the option to wait is more valuable with greater uncertainty $Vol_{i,t}$, and the investment responses to expected income growth is likely to be weaker. As a result, the interaction term $Growth_{i,t} \times Vol_{i,t}$ is expected to have a negative coefficient. Fifth, $Phy_{i,t}$ captures the physical condition of the property in period t, such as the age or condition of the roof, the HVAC, etc, which affects the need for capital improvements. Finally, we use period dummies to control for possible unusual capital improvements right after the acquisition or before the disposition that are driven by transactions.

It is important to note that the actual investment amount cannot be negative and thus is left censored. A panel Tobit model, therefore, is appropriate. However, since the final sample only includes properties with positive capital improvements over their entire holding periods, the Tobit model is reduced to a simple panel linear model. The next section provides a detailed discussion regarding the data cleaning process and the rationale for us to exclude properties with zero capital improvement, which basically cannot be distinguished from properties with missing capital improvement information.

Equation (1) is not estimable because some right side variables are not observed. First, the property owner's expected future income growth rate $Growth_{i,t}$, is unobserved. To overcome the problem, this paper employs the Gordon growth model (Gordon (1962)), which relates the cap rate to the discount rate $Dis_{i,t}$ and the expected income growth rate $Growth_{i,t}$. Specifically, the cap rate of property i in quarter t, denoted by $Cap_{i,t}$, is defined as the ratio of annualized income in quarter t, $F_{i,t}$, to the property value at the end of quarter $t-1$, $V_{i,t-1}$.

$$Cap_{i,t} = \frac{F_{i,t}}{V_{i,t-1}} \tag{3}$$

In the Gordon growth model, the income is assumed to be a growing perpetuity, and the property value $V_{i,t-1}$ equals the present value of all future income.

$$V_{i,t-1} = \frac{F_{i,t}}{Dis_{i,t} - Growth_{i,t}} \tag{4}$$

Relating equations (3) and (4), we have

$$Cap_{i,t} = Dis_{i,t} - Growth_{i,t}. \tag{5}$$

Two issues are worth noting regarding the cap rate. First, for $Growth_{i,t}$ in (5) to capture the *property owner's* expectation, the cap rate should be calculated using the *property owner's* valuation of the property. We assume that the quarterly *appraised* property values in the NCREIF database reflect property owner's valuation. This seems reasonable since *appraised values* in the database are produced by property owners themselves or appraisers hired by them. Second, the cap rate should be calculated using the normal or stabilized income for the property. However, in the data, the *reported* NOI is very volatile and thus may differ from what property owners think the stabilized NOI should be. To overcome this problem, we use the median cap rate of all properties of the same type (e.g. apartments or office) in the same Central Business Statistical Area (CBSA) as property i's cap rate $Cap_{i,t}$. The difference between the true *property* cap rate and the *median* CBSA cap rate is absorbed by the error term.

Now replace $Dis_{i,t} - Growth_{i,t}$ in (1) with the median CBSA cap rate, $Cap_{i,t}$, and replace the expected growth rate $Growth_{i,t}$ with $Dis_{i,t} - Cap_{i,t}$. Equation (1) becomes

$$\begin{aligned} Inv_{i,t} = {} & \alpha_i + \left(\rho_1 + \rho_2 Cap_{i,t}\right)\Delta Dis_{i,t} + \rho_3\left(Dis_{i,t} - Cap_{i,t}\right) + \rho_4 Vol_{i,t} \\ & + \rho_5\left(Dis_{i,t} - Cap_{i,t}\right) \times Vol_{i,t} + \rho_6 Phy_{i,t} + \rho_7 Buy_{i,t} + \rho_8 Sell_{i,t} + \varepsilon_{i,t}. \end{aligned} \tag{6}$$

The model in (6) still contains two unobserved variables. One is the physical condition of the property in period t, $Phy_{i,t}$. To overcome this problem, we decompose $Phy_{i,t}$ into two parts: the condition when the property is acquired, which is unobserved but can be captured by the property specific intercept term, and the *change* in the condition from the acquisition period to period t. We specify the second component as a linear function of three variables: the average capital improvement per period from acquisition to the previous period $Con_{i,t}$, the duration of the holding period from acquisition to period t $Hold_{i,t}$, and the squared duration $Hold2_{i,t}$. The duration and its squared value help capture nonlinear relationships between the property age since acquisition and the need for capital improvements. The average capital improvement from acquisition to the previous period is expected to have a negative coefficient on current capital improvement, because, holding constant the physical condition of the property at acquisition, the more capital improvement that has been done, the less is the need to maintain the physical condition. For the first quarter after acquisition, $Con_{i,t}$ is not defined and has no value. To avoid deleting the observation for the first period after acquisition, we let $Con_{i,t}$ for this quarter be the average capital improvement for the entire holding period. Note that this does not seem to affect the coefficient of the interaction term that we use to capture the non-monotonic effect of interest rate changes. The empirical results of this paper are robust if we do not include $Con_{i,t}$ in regressions.

The other unobserved variable is the property owner's discount rate. We assume that the discount rate is positively related to the 5-year Treasury bond yield $Int_{i,t}$ and includes an unobserved risk premium $v_{i,t}$.

$$Dis_{i,t} = \gamma \times Int_t + v_{i,t} \tag{7}$$

We use the 5-year Treasury bond yield so that the maturity of the risk free interest rate matches the average duration of holding period of commercial real estate, which is about 13 quarters (see, e.g. Peng (2010)).

To obtain an estimable model, we replace $Dis_{i,t}$ in (6) with $\gamma \times Int_t + v_{i,t}$, and use the error term to absorb $v_{i,t}$, replace the physical condition $Phy_{i,t}$ with a linear function of $Con_{i,t}$, $Hold_{i,t}$, and $Hold2_{i,t}$, and then re-parameterize (6) and obtain the following empirical model.

$$\begin{aligned} Inv_{i,t} = {} & \alpha_i + \beta_1 \Delta Int_t + \beta_2 \Delta Int_t \times Cap_{i,t} + \beta_3 Int_t + \beta_4 Int_t \times Vol_{i,t} \\ & + \beta_5 Cap_{i,t} + \beta_6 Vol_{i,t} + \beta_7 Cap_{i,t} \times Vol_{i,t} + \beta_8 Con_{i,t} + \beta_9 Hold_{i,t} \\ & + \beta_{10} Hold2_{i,t} + \beta_{11} Buy_{i,t} + \beta_{12} Sell_{i,t} + u_{i,t} \end{aligned} \tag{8}$$

In (8), $Inv_{i,t}$ is the log of capital improvement per square foot; Int_t and ΔInt_t are the level and the first order difference of the 5-year Treasury bond yields; $Cap_{i,t}$ is the median cap rate of all properties with the same type in the same Central Business Statistical Area (CBSA) as property i; $Vol_{i,t}$ is measured with the volatility of $Cap_{i,t}$, which can be measured in a cross-section or temporally; $Con_{i,t}$ is the log of the average capital improvement per square foot per quarter from acquisition to the previous quarter; $Hold_{i,t}$ and $Hold2_{i,t}$ are the holding period and the squared holding period from acquisition to quarter t; $Buy_{i,t}$ is a dummy that equals 1 if the property was acquired in quarter $t-1$ and 0 otherwise; $Sell_{i,t}$ is a dummy that equals 1 if the property was sold in quarter $t+1$ and 0 otherwise; α_i is a unobserved property dummy that captures property individual heterogeneity, including the physical condition of the property at acquisition. All the above variables are observed or can be calculated; therefore, the model can be estimated. Note that, in (8), the non-monotonic effect of interest rate changes is captured by β_2.

IV. Data

The 5-year Treasury yield is retrieved from the Federal Reserve Economic Data (FRED). The real estate data used in this paper are provided by the National Council of Real Estate Investment Fiduciaries (NCREIF), which is a not-for-profit institutional real estate industry association established in 1982. NCREIF collects, processes, and disseminates information provided by its members, who are mostly investment managers and plan sponsors who own or manage real estate in a fiduciary setting, regarding acquisition, operation, and disposition of institutional-quality commercial real estate. Using the compiled data, NCREIF constructs and reports the widely disseminated commercial real estate value appreciation and total return indices (NPIs).

The NCREIF database contains quarterly time series of physical attributes and operational information for each property owned or managed by NCREIF members since 1977:4. The sample period of the version of the database used in this paper ends in 2009:3. The total sample, after excluding properties with identical IDs but inconsistent zip codes and transaction records, comprises 23,771 properties. Physical attributes of each property include its location, property type (e.g. apartment, office, industrial or retail property, etc), gross square feet, etc. Operational information includes the net operating income (NOI), the capital improvement (CapEx), the appraised value, as well as the acquisition cost or the net sale proceeds if applicable. All operational information is on an unlevered basis. This paper focuses on the four main property types in the NCREIF data, which are apartment, office, industrial and retail properties, due to their large sample size (97% of the entire sample). Further, we estimate the empirical model in (8) separately for the four property types, due to the well known heterogeneity across property types (see, e.g. Peng (2010)).

We use the NCREIF database to construct the three key variables in the empirical analysis. The first is the time series of the median cap rate for each of the CBSAs where properties are located. The second is the time series of the cap rate uncertainty for the CBSAs. The third is the time series of capital improvements for each property. After constructing all three variables, we identify properties that have complete observations for all three variables over their entire holding periods, and include them in the final sample.

We first estimate the quarterly median cap rates for each CBSA using the NOI and appraised values of 22,076 out of the 23,771 properties in the NCREIF database. The excluded 1,695 properties include 1,458 properties that do not belong to the four major property types and 237 properties of which NOI is always 0, which likely indicates missing information. The estimation consists of the following three steps. First, the time series of the cap rate is calculated for each property in each quarter when both the NOI and the appraised value are observed. Second, the time series of the cap rate for each property is smoothed to eliminate “bumps” and “dents” that are likely caused by data errors. Specifically, a “bump” (“dent”) is identified as the maximum (minimum) of the cap rates that is 50% greater (smaller) than the average of the cap rates in the four nearest quarters. We replace each “bump” and “dent” with the average of the cap rates in the four nearest quarters. This smoothing procedure is repeated until no “bump” or “dent” exists. While the number of 50% is arbitrary, the empirical results are robust to the choice of the number of this threshold in a range from 30% to 80%. Third, for each CBSA in each quarter, if there are six or more observed cap rates from properties located in that CBSA, the median cap rate is calculated after excluding the maximum and the minimum cap rates across properties, which helps further mitigate possible errors. If there are fewer than six property cap rates, the CBSA cap rate is treated as unknown.

Figure 1 plots the time series of the cross-CBSA mean and the two standard deviations above and below the mean of the median cap rates for the CBSAs where properties in the final sample are located, for apartments, offices, and industrial and retail properties respectively. The cap rates show ostensible temporal variation, which seems to substantiate the well known “real estate cycles”.

For each calculated quarterly median CBSA cap rate, we construct two different measurements of the cap rate uncertainty in the same quarter. The first is the cross-sectional standard deviation of the property type specific cap rate, after excluding their maximum and minimum, in the CBSA and the quarter. The second is the cross-time standard deviation of the median CBSA cap rates in the past three quarters and the current quarter.

We next calculate the time series of capital improvement, which is measured with dollars (in 1983 dollars) per square foot per quarter. This calculation consists of the following steps. First, we try to fill in missing information regarding the gross square feet of each property. If a missing value is at the beginning (end) of the holding period of the property, we replace the missing value with the first (last) observed value. If a missing value is in the middle of the holding period, we check if the last observed value before and the first observed value after the missing value are equal. If they are, we replace the missing value with the last observed value. Otherwise, we make no change to the missing value.

Second, we identify properties that have both capital improvements and gross square feet observed during their entire holding periods, and then divide the quarterly total capital improvements (1983 dollars) with the gross square feet for each property. When identifying the properties, we first exclude 404 properties with unknown acquisition time, and thus unknown holding period. Second, we exclude 10,047 properties with missing capital improvements in some quarters during the holding period. Third, we exclude 1,021 properties of which the capital improvement is always 0, which might indicate that property owners never reported the actual capital improvements. Fourth, we exclude 792 properties with their holding periods shorter than four quarters, since these properties may represent opportunistic acquisitions. Fifth, we exclude 25 properties with missing information on gross square feet. Sixth, we exclude 153 properties that have highly inconsistent reported gross square feet across time. Specifically, if the maximum gross square feet of leasable space for a property exceeds twice the minimum during the holding period, we suspect a data error and remove this property from the sample. The above cleaning results in 9,634 properties. We then calculate the quarterly capital improvement per square foot for these properties.

Finally, we exclude outliers. A capital expenditure is an outlier if any of the following three variables, the sum, the mean, and the maximum of the capital improvement over the holding period, are among top 2.5% of their distributions. After excluding outliers, there are 9,276 properties for which we calculate the time series of capital improvements. Once the time series of capital improvement is calculated, we calculate the control variable $Con_{i,t}$ in (8), which is the log of the average capital improvement per square foot per quarter from acquisition to the previous quarter.

To compile the final sample of properties used in the empirical analysis, we first identify 6,978 properties that have all variables, including the capital improvement, the CBSA cap rates, and their uncertainty measures, observed over their entire holding period. We then notice that 3,198 properties have negative capital improvement in some quarters due to accounting corrections, and 4,516 properties have 0 capital improvements in some quarters. While the 0 capital improvement might be completely legitimate, reading the capital improvements for these properties indicates that a 0 capital improvement might indicate missing information. For example, some properties have fairly stable capital improvements in some quarters, and then have 0 for all the remaining quarters, which is possibly due to a change in the reporting behavior of the manager/owner instead of an accurate report of no capital improvements. Should the 0 capital improvement be legitimate, excluding these properties would reduce the sample size but does not bias the results. Should the 0s represent missing information, excluding them is desirable. Therefore, we choose to exclude all properties with negative or 0 capital improvements, and the final sample comprises 1,416 properties. Note that the results are robust when we include the excluded properties.

Table 1 reports summary statistics for each of the four types of properties in the final sample. The reported statistics include the number of CBSAs where the properties are located, the number of properties sold and not yet sold by 2009:3, the minimum, median, and maximum holding periods for properties that had been sold and had not been sold by 2009:3, and the minimum, median, and the maximum of the real acquisition prices (in 1983 dollars). The tables shows that the final sample comprises 676 apartment buildings, 402 office buildings, 250 industrial buildings, and 88 retail properties. The table also shows that property acquisition prices vary dramatically. For example, the lowest acquisition price for industrial properties is $0.23 million, while the highest is $470 million. The large price range seems to indicate that the sample is not biased in terms of property size.

Table 2 summarizes the temporal average and standard deviation of quarterly capital improvement ($ per square foot) for the four property types (1983 dollars). The reported statistics are the minimum, 25%, median, 75%, and the maximum of the cross property distributions of the temporal averages and standard deviations. The median temporal average capital improvement per square foot per quarter is about 18 cents for apartments, 64 cents for offices, 22 cents for industrial, and 44 cents for retails. The median of the temporal standard deviation is 15 cents for apartment, 59 cents for office, 19 cents for industrial, and 45 cents for retail properties. Figure 2 plots the histograms of the log capital improvement (log $ per square foot per quarter) of the final samples in the four property types respectively, which appears to indicate that the log normal distribution is appropriate in describing the capital improvement.

V. Empirical results

We first estimate the parameters of a fixed effect panel regression for the four property types respectively, using the cross-sectional measure of the cap rate volatility. Table 3 reports the estimation results, which provides strong evidence for the non-monotonic effect of interest rate changes on the capital improvement for apartment, office, and retail properties, but no evidence of this relationship for industrial properties. Specifically, the coefficient of the interaction term between the change in the interest rate and the cap rate is statistically significant at the 1% level for apartments, and at the 5% level for office and retail.

We use simulations to illustrate the magnitude of the non-monotonic effect of interest rate changes on capital improvements for apartment, office, and retail properties respectively. For each property type, assuming that the interest rate decreases by 50 basis points, we randomly draw 10,000 sets of coefficients β_1 and β_2 from the Normal distribution of the coefficient estimators. For each set of β_1 and β_2, we calculate $\beta_1 \Delta Int_t + \beta_2 \Delta Int_t \times Cap_{i,t}$ with ΔInt_t being fixed at 0.05 (50 basis points), and $Cap_{i,t}$ ranging between 4% and 10%. Since the dependent variable is the log of the capital improvement, the exponential of $\beta_1 \Delta Int_t + \beta_2 \Delta Int_t \times Cap_{i,t}$ has a straightforward interpretation – it equals the percentage change in the capital improvement as the result of the change in the interest rate, and this percentage change is a function of the cap rate. Using the 10,000 sets of drawn coefficients, we are able to construct the percentiles of the percentage changes in the capital improvement for different cap rates.

Figure 3 plots the 5%, the median, and the 95% of the distribution of the percentage changes in the capital improvement against the cap rate for apartments. It is clear that the effect decreases with the cap rate. Specifically, when the cap rate is low, say 4%, the median effect is about 18%, which means that the capital improvement increases by about 18% if the interest rate decreases by 50 basis points. However, when the cap rate is high, say 10%, the median effect is only 4%. Figures 4 and 5 plot the same percentiles for office and industrial properties, and both illustrate similar patterns: that the effect of a decrease in the interest rate is a decreasing function of the cap rate. It is worth noting that the non-monotonic effect seems stronger for retail properties than for apartments and office: the effect decreases from 31%, when the cap rate is 4%, to 0, when the cap rate is about 7.5%.

Table 3 also indicates that variables other than interest rate changes also influence capital improvements. First, a change in the cap rate has a negative influence on capital improvements, and the effect is statistically significant at the 1% level for apartment and office properties, but insignificant for industrial and retail properties. The negative effect of the cap rate is consistent with the notion that the lower is the cap rate, the higher is the expected growth rate of future NOI or the lower is the cost of capital, both of which indicates higher NPV of new investment and thus more expenditures on capital improvements. Second, the physical condition of the property, which is measured with the quarterly average of capital improvement from acquisition to the previous quarter, has a negative effect on the capital improvement. This result is sensible – holding constant the initial physical condition of a property at acquisition, the more capital improvement since acquisition, the better is the current physical condition of the property, and the less is the need for capital improvement. Third, the holding period and its squared value have significant effects for apartment, industrial, and retail properties. This is consistent with the notion that, holding constant the age of the property at acquisition, the need for capital improvement changes with the holding period as the property ages. Finally, the dummy for the quarter after acquisition is negative and statistically significant for apartment, office, and industrial properties, and the dummy for the quarter before the transfer of ownership is significantly positive for all property types. This seems to indicate that property owners less likely invest in capital improvement immediately after the acquisition, and more likely invest immediately before the disposition.

It is worth noting that Table 3 provides little evidence for the effect of the cap rate volatility on capital improvement. The coefficient for the cap rate volatility is insignificant for apartment, office, and industrial properties, and is significantly negative for retail properties. In addition, Table 3 provides no evidence for the real option effect, which is captured by the interaction term between the cap rate and the cap rate volatility. Real option theory predicts that the effect of the expected income growth rate is dampened by the volatility of the expected growth rate, and thus the coefficient of the interaction term is expected to be significant. However, it is not different from 0 for all four property types.

A possible reason why Table 3 provides no evidence for the effect of the cap rate volatility and the real option effect is that perhaps the cap rate volatility is not measured accurately. To investigate this possibility, we reproduce the regressions in Table 3 but use a temporal measure of cap rate volatility. These results are reported in Table 4. It is worth noting that Table 4 still provides strong evidence for the non-monotonic effect of interest rate changes. Specifically, the coefficient of the interaction term between the interest rate change and the cap rate is statistically significant for apartment, office, and retail properties. Further, other significant variables shown in Table 3, including the cap rate, the physical condition, the holding period, and the dummies for quarters after acquisition and before ownership transfer, remain statistically significant. Table 4 still provides little evidence for the effect of the cap rate volatility – the coefficient is only significant for apartments, and the real option effect – the interaction term between the cap rate and the cap rate volatility--is only significant for retail properties.

We conduct a series of robustness checks by changing the data cleaning procedure and then re-estimate (8). First, when excluding possible opportunistic acquisitions, we exclude properties that have holding periods shorter than 6 quarters instead of 4 quarters. Second, when excluding capital improvement outliers, we try a variety of different thresholds, including the top 1%, 1.5%, and 3%, instead of the top 2.5%. Third, instead of filtering out all properties with at least one 0 capital improvement, we keep them in the sample. The non-monotonic effect of interest rate changes survives all these robustness checks[2], so the strong evidence of the effect do not seem to be driven by the specific data cleaning procedure we use.

VII. Conclusion

This paper empirically analyzes a non-monotonic effect of interest rate changes on irreversible investment, which is that the investment response to interest rate changes depends on the difference between the interest rate and the expected future income growth rate. Using the complete history of quarterly capital improvement for 1,416 commercial properties over the 1978 to 2009 period, we find strong evidence of the non-monotonic effects for apartment, office, and retail properties, but no evidence for industrial properties. For the first three property types, a decrease in the Treasury yield dramatically increases capital improvements when property values are high (or when cap rates are low), but has a weak or negative influence when properties have low valuation (high cap rates). This result has a clear and important policy implication. If a decrease in the interest rate does not necessarily stimulate investment, then monetary authorities should take extreme care when they try to use interest rate changes to promote investment.

[2] These results are available from the authors.

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Table 1 Data Summary: Properties

This table reports the following summary statistics for the final samples of apartment, office, industrial and retail properties respectively: the number of different CBSAs where properties are located, the number of properties that had been sold and not sold by 2009:3, the minimum, median, and maximum of the holding periods of properties that had been sold and not sold, the minimum, median, and maximum of the real acquisition price ($ millions in 1983 dollars).

	Apartment	Office	Industrial	Retail
CBSAs	36	32	32	25
Properties				
Sold by 2009:3	309	192	170	49
Not Yet Sold	367	210	80	39
Total	676	402	250	88
Holding Period for Sold Properties				
Min	5	5	5	5
Median	14	12	9	12
Max	70	38	56	25
Holding Period for Properties Not Yet Sold				
Min	4	4	4	7
Median	13	12	13	12
Max	57	48	51	29
Acquisition Price ($ millions)				
Min	2.09	1.45	0.23	2.84
Median	13.57	22.10	10.22	14.77
Max	234.50	453.49	470.25	261.33

Table 2 Data Summary: Capital Improvements

This table reports the cross property distributions of the temporal averages and standard deviations of capital improvements ($ per square foot per quarter) for the final samples of apartment, office, industrial and retail properties (in current or $1983?).

		Apartment	Office	Industrial	Retail
Average					
	Minimum	$0.01	$0.02	$0.01	$0.02
	25%	$0.10	$0.44	$0.12	$0.19
	Median	$0.18	$0.64	$0.22	$0.44
	75%	$0.38	$1.04	$0.48	$1.05
	Maximum	$5.30	$5.54	$4.95	$4.30
Standard Deviation					
	Minimum	$0.01	$0.03	$0.01	$0.03
	25%	$0.07	$0.35	$0.10	$0.16
	Median	$0.15	$0.59	$0.19	$0.45
	75%	$0.35	$0.96	$0.44	$0.89
	Maximum	$7.70	$7.28	$8.18	$11.89

Table 3 Interest Rate Changes and Capital Improvements: Cross Sectional Volatility of Cap Rates

This table reports results that analyze the determinants of capital improvements for apartment, office, industrial and retail properties, respectively, using cross-sectional volatility in cap rates to measure volatility.

$$Inv_{i,t} = \alpha_i + \beta_1 \Delta Int_t + \beta_2 \Delta Int_t \times Cap_{i,t} + \beta_3 Int_t + \beta_4 Int_t \times Vol_{i,t} + \beta_5 Cap_{i,t} + \beta_6 Vol_{i,t}$$
$$+ \beta_7 Cap_{i,t} \times Vol_{i,t} + \beta_8 Con_{i,t} + \beta_9 Hold_{i,t} + \beta_{10} Hold2_{i,t} + \beta_{11} Buy_{i,t} + \beta_{12} Sell_{i,t} + u_{i,t}$$

In the above model, for property i in quarter t, $Inv_{i,t}$ is the log of capital improvement per square foot; Int_t and ΔInt_t are the level and the first order difference of the 5-year Treasury bond yield; $Cap_{i,t}$ is the median cap rate of all properties in the same Central Business Statistical Area (CBSA) as property i; $Vol_{i,t}$ is the volatility of $Cap_{i,t}$, which is measured with the cross-property standard deviation of property cap rates in the same CBSA in quarter t; $Con_{i,t}$ is the physical condition of the property, which is measured with the average capital improvement per square foot per quarter since acquisition; $Hold_{i,t}$ and $Hold2_{i,t}$ are the holding period and the squared holding period from acquisition to quarter t; $Buy_{i,t}$ is a dummy variable that equals 1 if the property was acquired in quarter $t-1$ and 0 otherwise; $Sell_{i,t}$ is a dummy variable that equals 1 if the property was sold in quarter $t+1$ and 0 otherwise; α_i is a unobserved property dummy that captures property individual heterogeneity. Heteroskedasticity-robust standard deviations are in parentheses. ***, **, and * indicate a significant level of 1%, 5%, and 10% respectively.

	Apartment	Office	Industrial	Retail
ΔInt_t	***-49.08	***-46.52	*-4.28	**-115.54
	(7.50)	(15.67)	(2.31)	(46.53)
$\Delta Int_t \times Cap_{i,t}$	***419.38	**467.44	359.49	**1533.40
	(116.02)	(221.20)	(285.68)	(646.33)
Int_t	1.23	7.06	3.69	-7.94
	(3.48)	(5.97)	(6.90)	(11.20)
$Int_t \times Vol_{i,t}$	*600.90	-247.82	-73.42	**1793.05
	(325.15)	(289.65)	(330.99)	(799.04)
$Cap_{i,t}$	***-10.22	***-17.56	-11.64	-13.22
	(3.62)	(6.33)	(9.01)	(20.65)
$Vol_{i,t}$	-30.40	30.41	-26.74	*-189.95
	(19.40)	(26.07)	(40.97)	(101.01)
$Cap_{i,t} \times Vol_{i,t}$	116.85	-273.37	540.80	1602.50
	(337.23)	(314.23)	(474.17)	(1339.05)
$Con_{i,t}$	**-0.07	-0.051	***-0.32	**-0.16
	(0.03)	(0.039)	(0.06)	(0.08)
$Hold_{i,t}$	***-0.03	-0.00	-0.01	**0.07
	(0.00)	(0.01)	(0.01)	(0.03)
$Hold2_{i,t}$	***0.00	-0.00	0.00	**-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$Buy_{i,t}$	**-0.10	***-0.49	*-0.19	0.03
	(0.05)	(0.09)	(0.09)	(0.22)
$Sell_{i,t}$	*0.10	***0.41	**0.25	***0.57
	(0.06)	(0.10)	(0.12)	(0.18)
Properties	676	402	250	88
Sample size	10,653	5,115	3,007	1,042
Adj. R2	0.05	0.04	0.03	0.03

Table 4 Interest Rate Changes and Capital Improvements: Time Series Volatility of Cap Rates

This table reports results that analyze the determinants of capital improvements for apartment, office, industrial and retail properties, respectively, using temporal volatility in cap rates to measure volatility.

$$Inv_{i,t} = \alpha_i + \beta_1 \Delta Int_t + \beta_2 \Delta Int_t \times Cap_{i,t} + \beta_3 Int_t + \beta_4 Int_t \times Vol_{i,t} + \beta_5 Cap_{i,t} + \beta_6 Vol_{i,t}$$
$$+ \beta_7 Cap_{i,t} \times Vol_{i,t} + \beta_8 Con_{i,t} + \beta_9 Hold_{i,t} + \beta_{10} Hold2_{i,t} + \beta_{11} Buy_{i,t} + \beta_{12} Sell_{i,t} + u_{i,t}$$

In the above model, for property i in quarter t, $Inv_{i,t}$ is the log of capital improvement per square foot; Int_t and ΔInt_t are the level and the first order difference of the 5-year Treasury bond yield; $Cap_{i,t}$ is the median cap rate of all properties in the same Central Business Statistical Area (CBSA) as property i; $Vol_{i,t}$ is the volatility of $Cap_{i,t}$, which is measured with the standard deviation of the CBSA cap rates in the past three and current quarter; $Con_{i,t}$ is the physical condition of the property, which is measured with the average capital improvement per square foot per quarter since acquisition; $Hold_{i,t}$ and $Hold2_{i,t}$ are the holding period and the squared holding period from acquisition to quarter t; $Buy_{i,t}$ is a dummy variable that equals 1 if the property was acquired in quarter $t-1$ and 0 otherwise; $Sell_{i,t}$ is a dummy variable that equals 1 if the property was sold in quarter $t+1$ and 0 otherwise; α_i is a unobserved property dummy that captures property individual heterogeneity. Heteroskedasticity-robust standard deviations are in parentheses. ***, **, and * indicate a significant level of 1%, 5%, and 10% respectively.

	Apartment	Office	Industrial	Retail
ΔInt_t	***-45.50	***-39.79	-35.61	**-104.77
	(7.62)	(15.70)	(22.95)	(46.56)
$\Delta Int_t \times Cap_{i,t}$	***386.28	*399.52	292.14	**1357.44
	(116.65)	(221.53)	(283.43)	(642.89)
Int_t	**4.05	1.68	-3.22	-0.99
	(1.95)	(3.65)	(3.92)	(8.96)
$Int_t \times Vol_{i,t}$	*1072.22	1067.74	*1304.74	***5202.44
	(584.69)	(672.39)	(752.88)	(1915.54)
$Cap_{i,t}$	***-10.08	***-19.74	0.67	*24.19
	(2.39)	(4.19)	(4.79)	(13.99)
$Vol_{i,t}$	**-107.20	-40.08	-54.98	160.15
	(32.44)	(51.73)	(80.95)	(152.33)
$Cap_{i,t} \times Vol_{i,t}$	942.58	252.56	-156.24	**-4775.14
	(605.31)	(761.61)	(966.18)	(2230.13)
$Con_{i,t}$	**-0.07	-0.05	***-0.32	**-0.17
	(0.03)	(0.04)	(0.06)	(0.08)
$Hold_{i,t}$	***-0.03	-0.00	-0.00	**0.07
	(0.00)	(0.01)	(0.01)	(0.03)
$Hold2_{i,t}$	***-0.00	0.00	-0.00	**-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$Buy_{i,t}$	**-0.10	***-0.48	*-0.19	0.04
	(0.05)	(0.09)	(0.10)	(0.22)
$Sell_{i,t}$	*0.11	***0.40	**0.24	***0.57
	(0.06)	(0.10)	(0.12)	(0.20)
Properties	676	402	250	88
Sample size	10,653	5,115	3,007	1,042
Adj. R2	0.05	0.04	0.03	0.04

Figure 1. CBSA Cap Rates

This figure plots the time series of the mean and two standard deviations above and below the mean of the CBSA median cap rates, for apartment, office, industrial and retail properties respectively.

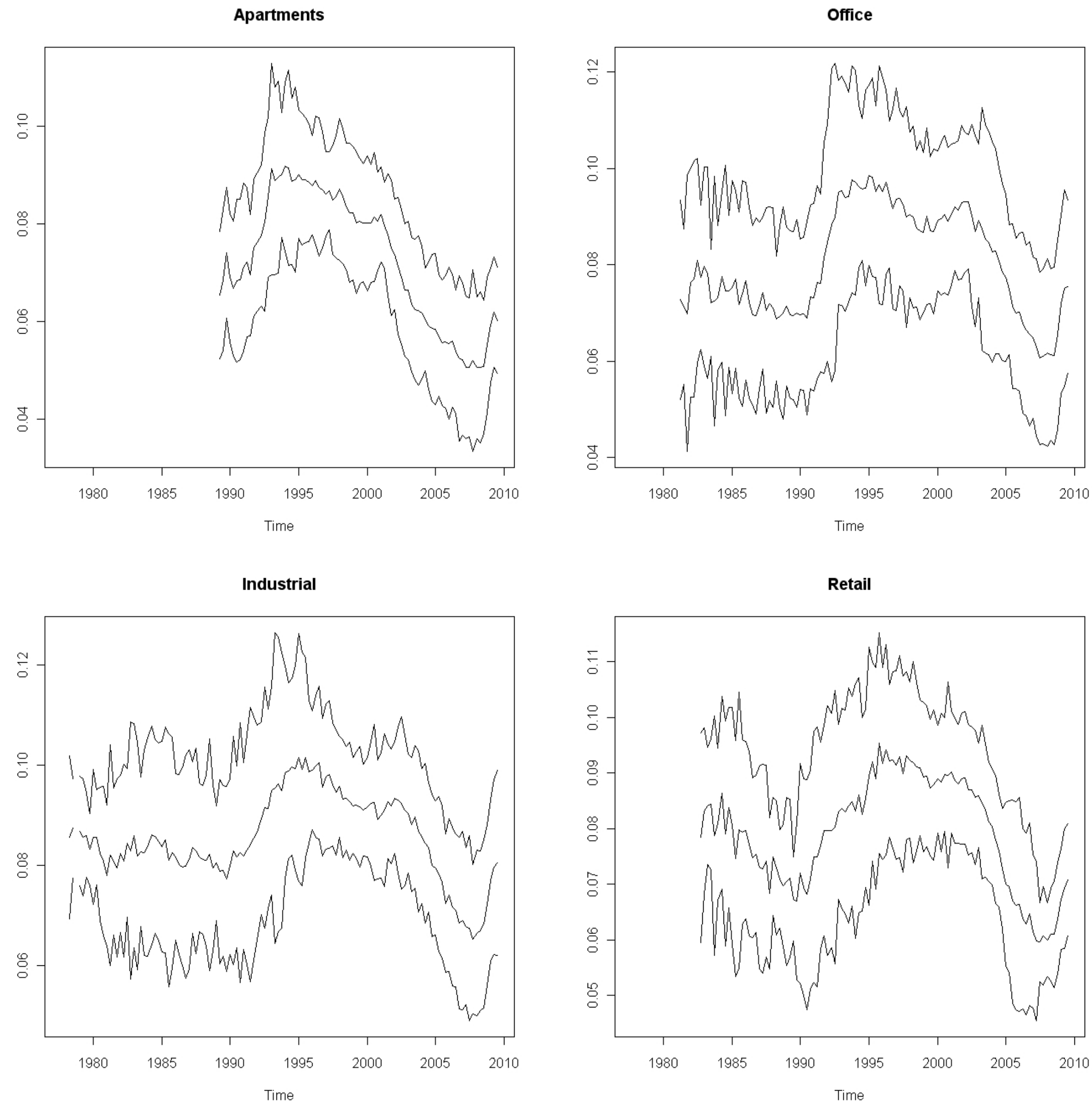

Figure 2. Property CapEx per Square Foot (Log)

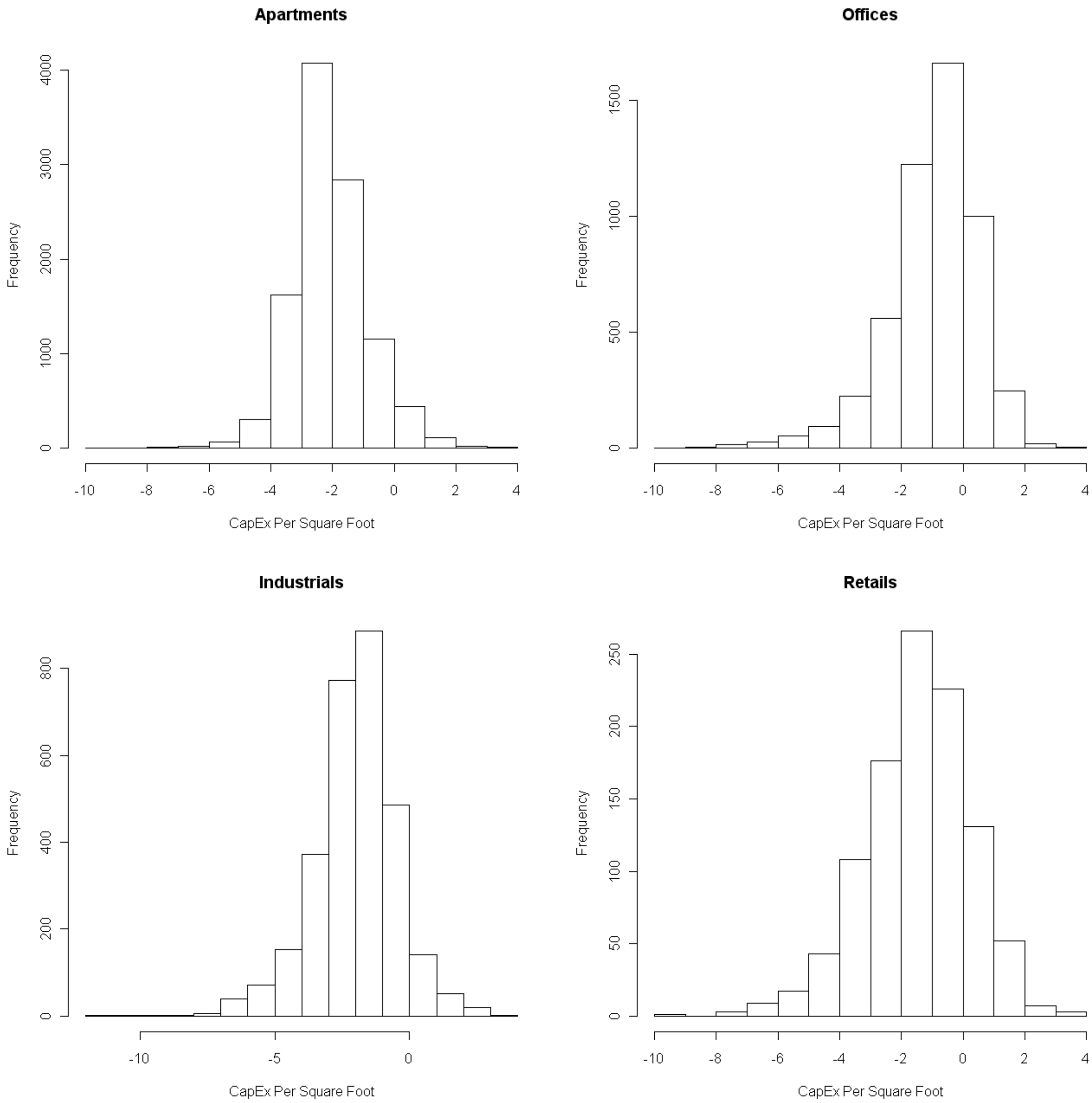

Figure 3. Interest Rate Changes and Capital Improvement

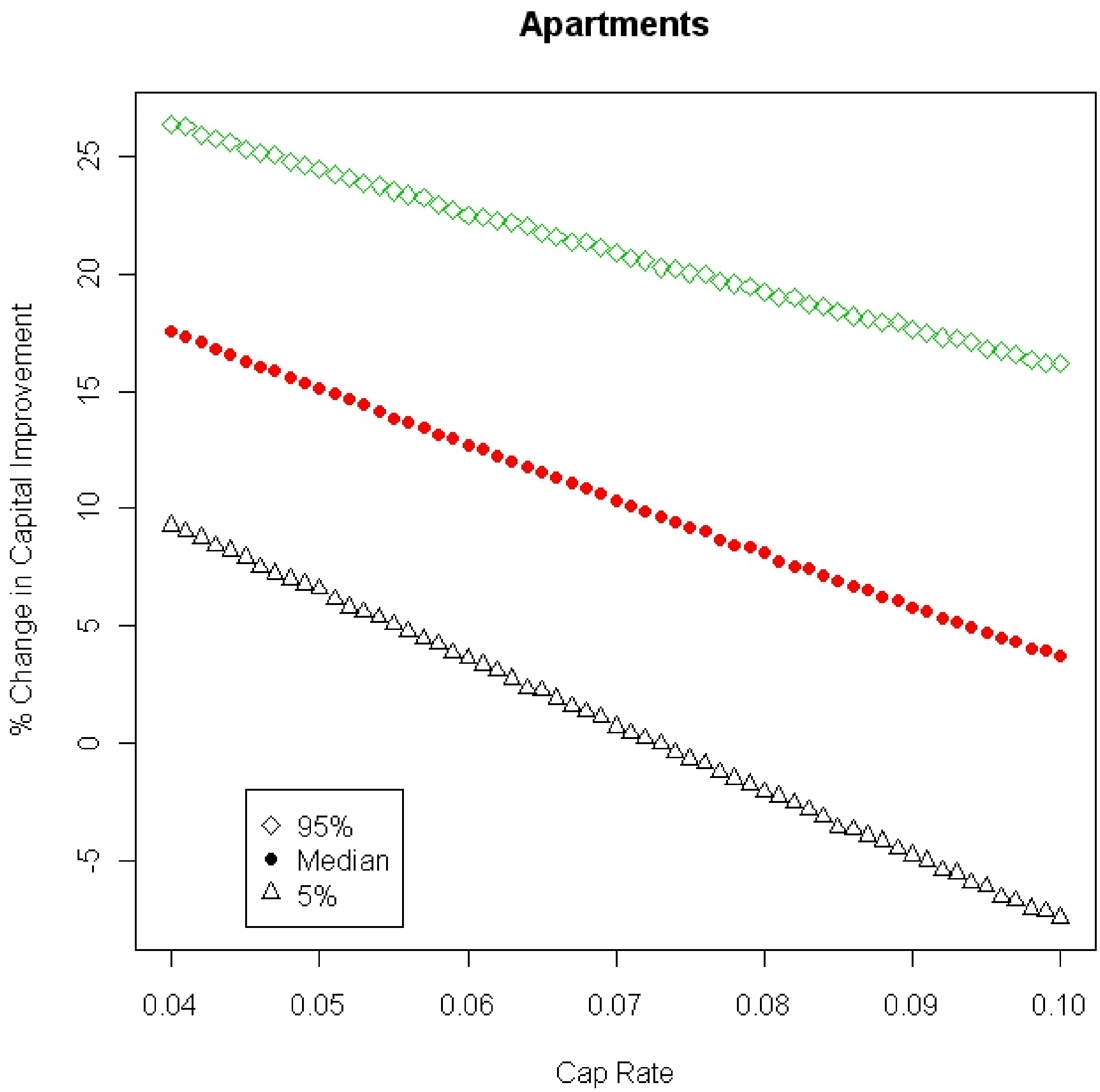

Figure 4. Interest Rate Changes and Capital Improvement

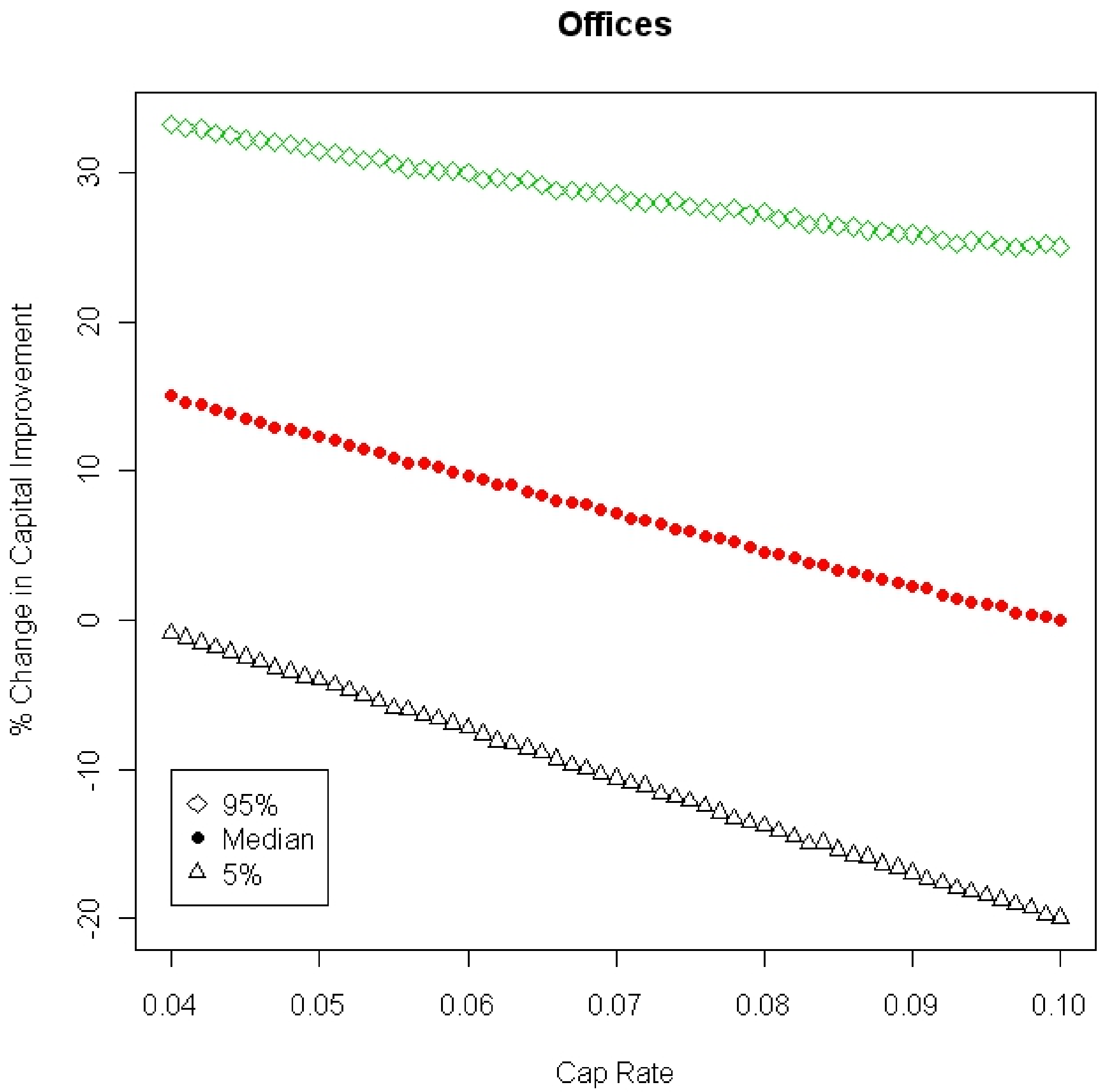

Figure 5. Interest Rate Changes and Capital Improvement