EFFECTS OF UNCERTAINTY ON THE INVESTMENT DECISION:

AN EXAMINATION OF THE OPTION-BASED INVESTMENT MODEL USING JAPANESE REAL ESTATE DATA

by

Jiro Yoshida

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SUBMITTED TO THE DEPARTMENT OF URBAN STUDIES AND PLANNING
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT

This paper examines the validity of the option-based investment model as opposed to the neoclassical investment model in the decision-making of commercial real estate development, using aggregate real estate data from Japan. I particularly focus on the effect of uncertainty because it is the central difference between the two models. I specify a structural model in order to incorporate the interactions between supply and demand in the real estate asset market. In order to conduct detailed empirical tests for a long period of time, I set three data series. The Long Series uses quarterly data of 25 years and Short Series 1 and Short Series 2 use monthly data of about 15 years. I find strong evidence that supports the option-based investment model. Especially in the supply equation, total uncertainty has significant effects on the investment decision. A lag structure is found in the effect of total uncertainty. The parameters for other variables also generally favor the option-based model. In the demand equation, too, the results strongly support the option-based investment model. It should be concluded from these results that various kinds of real options must be incorporated in investment and economic models.

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1. Introduction

We are living in a world of uncertainty. We do not know what will happen tomorrow, or even in ten minutes. People try their best to estimate the future conditions at their best but also know that such estimations sometimes succeed and sometimes fail. Even though the estimation techniques have been refined, the future is still fairly uncertain. In ordinary life, therefore, people often try to remain as flexible as possible or to postpone their decisions for as long as possible. People intuitively compare the costs and benefits of fixing the future and seek the best timing to decide. In business, therefore, a special "insight" that cannot be formally explained has always been highly valued, until recently, because there has not been any method to consider explicitly the effects of uncertainty. In economics, however, the recent development of "Real Options Theory" has started to deal with the effects of uncertainty on the investment decision and the economy.

Purpose of the study

The purpose of this thesis is to review the real options theory and to examine the validity of the option-based investment model as opposed to the neoclassical investment model in the decision-making about the commercial real estate development, using aggregate real estate data from Japan. The most typical difference between these two types of models is their treatments of risks. Widely accepted neoclassical investment models account for only systematic risk on only the demand side of asset markets. However, the option-based investment models predict that uncertainty significantly affects the demand and supply schedules in a way that the neoclassical models have not considered.

Uncertainty significantly affects asset markets in several ways according to the option-based model. In addition to the demand side effect of the systematic portion of risk shown in the neoclassical theory, the systematic risk also changes the supply schedule by changing the value of option to wait in the option-based model. A greater systematic risk shifts the supply curve to the right because of the less value of option to wait. In the option-based model, the total uncertainty also shifts the demand schedule by changing the option value to abandon or redevelop if the investor can choose to abandon or redevelop the asset. If the total uncertainty increases, the value of abandonment option and redevelopment option increases and the asset has a higher price. The total uncertainty also alters the supply schedule by changing the value of option to wait. However, greater total uncertainty shifts the supply curve to the left, which is the opposite direction to the one caused by the systematic risk. The point is that uncertainty affects equilibrium price and quantity in asset markets in various ways. In this paper I focus mainly on the effects on the supply side.

Theoretical works on the option-based model or real options have already brought a series of rich and persuasive conclusions since the 1970's. Empirical studies, however, have not been conducted much due to the lack of data. In Japan, especially in Japanese real estate economics, even the concept of real options is not widely recognized. This study is the first to examine the validity of the option-based investment model using the Long Series of aggregate data from the Japanese real estate market.

This paper focuses on the underlying forces on the investment decision in the Japanese real estate market. The importance of capital investment, especially in the current economic situation in Japan, is beyond dispute[1]. The ratio of private capital investment to GNP in Japan is especially high, ranging between 13% and 20%. Real estate is one of the most important assets

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[1] See Kawasaki and Tsutsumi (1996) for the discussion of capital underinvestment as a main cause of economic

in the investment universe. In both the United States and Japan, total capitalization of real estate is estimated to reach almost a third of all gross national assets[2]. Therefore, the changes in real estate investment significantly affect the Japanese economy. It is quite important to understand properly the real estate investment decision.

However, there are various unexplained behaviors regarding the investment decision. This study is important because it may help to explain some of these unsolved problems in Japan. Why does the monetary policy of extremely low interest rates fail to stimulate investments? Why do Japanese firms tend to ignore the traditional Discounted Cash Flow (DCF) model in their capital budgeting? Why do new constructions of real estate tend to show booms and busts? Why do investors hesitate to invest after bad economic conditions even if the conditions have recovered? Each of these problems is quite important, but is normally considered the consequence of irrational behavior. Real-options theory may provide a rational foundation for these seemingly irrational behaviors and a way to quantify the value of contingent claims. Eventually, real options may alter the decision-making rules in corporate finance and the policy planning by the government. This paper examines how well the option-based model explains these problems.

Plan of actions to address issues

I first review the Japanese institutional and economic context in the next section, particularly focusing on the uncertainty. Then in Section 3, I review the basic real-options theory and compare it with neoclassical theory, especially emphasizing their implications for the real

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stagnation.

[2] See Miles et al. (1994) for the case of the United States. See Annual Report on National Accounts (The Economic Planning Agency) for Japanese case.

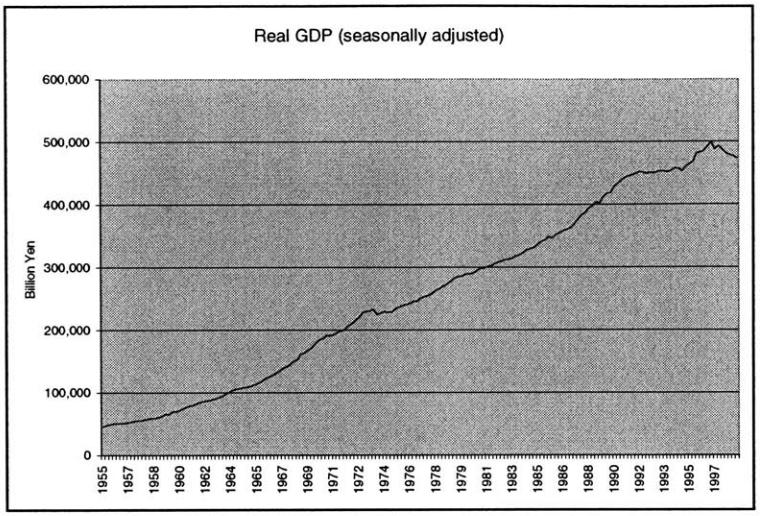
estate market. I also review the previous empirical studies dealing with the option-based investment model. In Section 4, I specify the structural model based on the one constructed by Holland, Ott and Riddiough (1999). The variables included in the model are asset prices, the level of investment, expected rent, construction cost, risk-free rate of interest, expected growth, systematic risk and total uncertainty. I include total uncertainty in both the demand and supply equation in order to incorporate the effects of various options such as development option, redevelopment option and abandonment option. The data used to estimate the model is examined both qualitatively and quantitatively in Section 5. I use three data series that consist of the Japanese macro data and the aggregate data of the real estate and construction industry. The Long Series uses quarterly data from 1974 to 1998 to examine the effects under various economic conditions. Short Series 1 and Short Series 2 use monthly data from 1982 to 1998 and from 1986 to 1998, respectively. After showing the qualitative relationships between investments and uncertainty, I examine and specify the data applied to the estimation of the model. As a result of stationality and co-integration tests, the model is specified using the first difference of each variable. Two Stage Least Square method is used in the model estimation. Section 6 discusses the obtained results and Section 7 concludes.

Findings

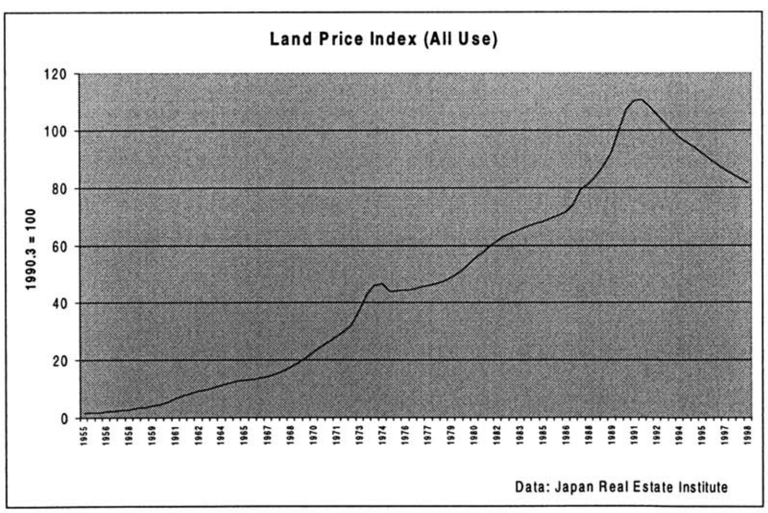
I find strong evidence that supports the option-based investment model as opposed to the neoclassical model. Especially in the supply equation, total uncertainty has significant effects on the investment decision. The estimated parameters indicate that a one-standard-deviation increase in total uncertainty reduces investments by 19% on a quarterly basis and by 3% on a monthly basis. Total uncertainty affects investments with a lag of two to twelve months and these lags have been shortened in recent years probably due to a more competitive market condition. The parameters for other variables such as systematic risk, asset price, construction cost, risk-free rate of interest and expected growth also generally favor the option-based model although some parameters do not show sufficiently strong support. In the demand equation, too, the results strongly support the option-based investment model. Statistically and economically significant positive parameters of total uncertainty in the demand equation indicate that the asset market takes into account real options embedded in assets. It should be concluded from the result obtained in this paper that the real options significantly affect the real estate investment decision in Japan, and thus, various kinds of real options must be incorporated in investment and economic modeling for the use of business, academics or public policy.

2. Japanese Institutional and Economic Context

It is widely considered that Japan has entered a period of uncertainty. Japan achieved surprising economic development after World War II. Since the late-70's until the burst of the notorious "Bubble Economy" in 1991, the Japanese economy had been expected to keep stable growth[3]. Therefore, people considered the Japanese economy and society fairly certain[4] especially from the mid-70's until the late 80's. During the period of the "Heisei Economic Boom" or "Bubble Economy" between 1986 and 1991, in particular, people were confident about the Japanese economy and it was widely accepted that the economy would continue growing into the foreseeable future.



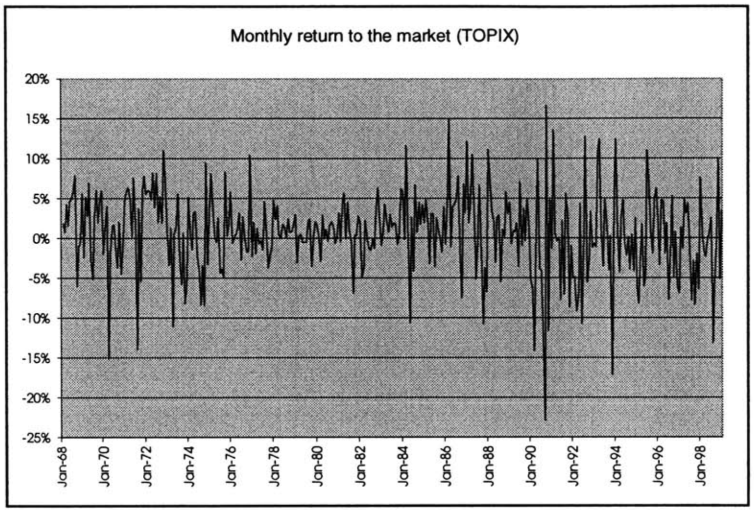
Real estate was especially seen as a certain or safe asset to invest in because people believed that its scarcity in Japan[5] would drive the appreciation forever. The



[3] The only big decline in real GDP between 1955 and 1991 was the one after the First Oil Crisis in 1973.
[4] The certainty of the society has also been supported by the social systems such as lifetime employment, Keiretsu-system and industrial policies.
[5] Habitable area is about only 30% of national land area.

belief of perpetual growth in land value was called, the "Myth of Land Value" and had permeated Japan. A large number of people struggled to buy real estate hoping for huge capital gain.

However, after the crash of the stock market in 1990 and of the real estate market in 1991, people started to have the opposite mind set. People lost their confidence in the Japanese economy, and not only shifted their growth expectation downward, but also recognized that the future is quite uncertain. The return to the market fluctuates widely today. The loss of self-confidence has initiated restructuring and deregulation in many areas of Japanese society in pursuit of a new social system in the global economy. The restructured areas include public administration, the public pension plan, education, financial industry, construction industry, and airline industry, to name a few. Japanese society is now changing to a more fast and unstable one that emphasizes self-responsibility. As a consequence, people think that the future is quite uncertain. People cut their consumption for fear of unemployment and firms hesitate to start new investment for fear of worse market conditions in the future. Many industries including real estate have started to recognize the future markets as cyclical and volatile.



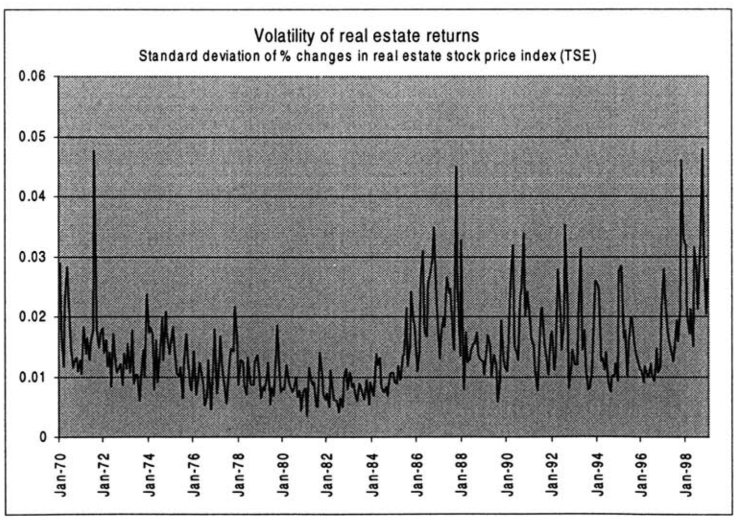
It is worthwhile reviewing the history of the Japanese economy focusing on the increased uncertainty (see also Appendix for the history of the Japanese economy). Although the neoclassical model is not the main concern of this paper, for now I will use the neoclassical framework to relate uncertainty and the recent downturn of asset prices[6]. In Section 6, I consider how the option-based model can better explain the aggregate economy.

According to the DCF model, the asset price demanded by investors can be expressed as the following:

$$P_t = \frac{CF_{t+1}}{r_f + RP - g}$$

where P_t is the asset price as of time t, CF_{t+1} is expected cash flow in the next period, r_f is risk-free rate of interest, RP is risk premium of the asset, and g is expected growth rate.[7]

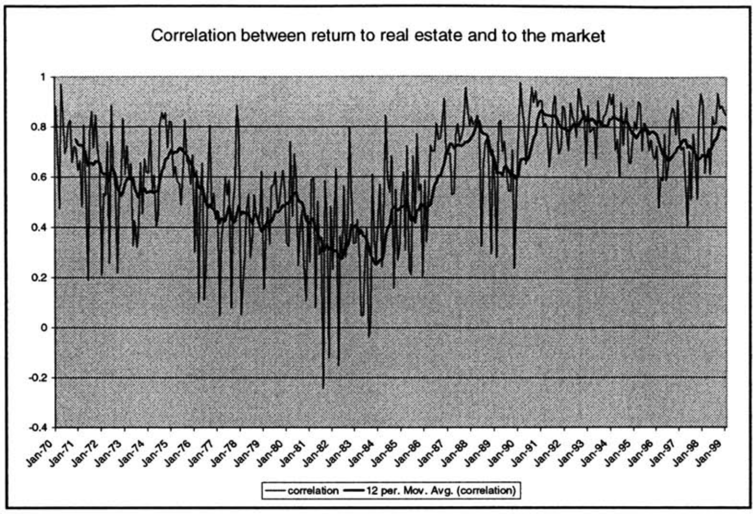
Each of the four variables on the right side of the equation can alter P_t. First, growth expectation might have shifted downward. A lower growth expectation reduces the price ($\frac{\partial P}{\partial g} > 0$) by making the denominator of the above formula bigger. A small change in the growth expectation can lead to a huge change in the price. In real estate markets, it is easily imagined that the disappearance of the Myth of Land Price resulted in a big reduction in growth expectation. In addition, a lower (negative) realized growth might have shifted the growth expectation further.

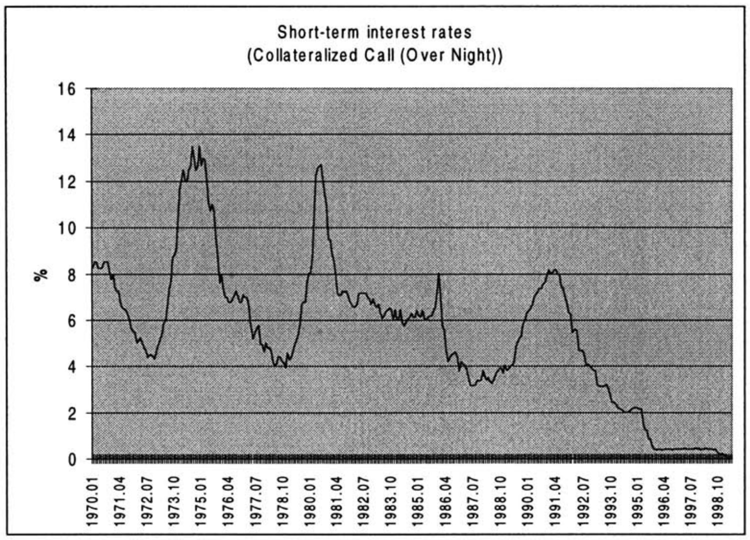


Second, the risk premium might have increased. Because $\frac{\partial P}{\partial RP} < 0$, price must be reduced. The

[6] Asset price changes are typically explained from demand side in Japan and typically attributed to the changes in cash flows, interest rates and expected growth. Or price levels are compared with GDP. See Tanaka (1999) and Uemura et al. (1997). Other studies focus on the liquidity in money market and arbitrage among asset classes. See Oya (1990) and Uemura et al. (1997). However, the changes in the risk premium are not usually discussed.
[7] I am assuming here a flat yield curve and a constant growth in cash flows.

risk premium of an asset is determined by the volatility of expected cash flows and correlation with market portfolio. Judging from the facts that both the volatility of real estate returns[8] and the correlation between real estate return and the market return[8] has increased since the late-1980's, it is likely that both volatility and correlation increased the risk premium of real estate.





Third, expected cash flow of the following period might have decreased. At least realized cash flows declined since 1991. Decreased expected cash flows drive the price down ($\frac{\partial P}{\partial CF_{t+1}} > 0$).

Fourth, risk-free rate of interest is considered to mitigate the market crash, because after 1991 it was cut steadily and currently remains nearly zero. Lower risk-free rate is the force to raise the price since $\frac{\partial P}{\partial r_f} < 0$.

The analysis above is focusing on the demand side of the asset market. If an asset

[8] Real estate return and the market return are calculated as daily return on the real estate stock index (TSE) and TOPIX, respectively.

market is quite efficient and demand is quite elastic, the above argument can be directly applied because the equilibrium price is determined by the demand (i.e. the formula above). If the asset demand has a downward slope, the equilibrium price cannot be determined without considering supply. The real estate market in Japan is not thought to be a quite efficient market because of information frictions, transaction costs and traditional business practices. Therefore, I will specify an equilibrium model in Section 4 to incorporate the interactions between supply and demand when examining the effects of uncertainty on the real estate asset market, and show how the option-based model explain well the real estate asset market.

There is a fact that implies the validity of the option-based investment model. Japanese firms seem to have ignored modern finance theory (i.e. neoclassical models). Japanese companies seldom use the DCF method in capital budgeting, or even if they do use it, they do not put much emphasis on it. For example, Toyota Motors Corporation built a new plant in Japan that was less efficient but more flexible. Toyota made this decision although a typical Net Present Value (NPV) calculation might have concluded that the plan is inferior. Toyota might have been seen as irrational by neoclassical standards but the option-based investment model may conclude that this decision rational. There are a number of similar examples in Japanese businesses. They might implicitly take into account the real-options value. If this type of decision governs Japanese asset markets, the option-based investment model may fit the Japanese market very well.

Apart from economics, real options may help explain several important sociological phenomena in Japan. The delay of marriage and decrease in birthrate are two important problems in Japanese society. They are normally explained by such factors as the maturity of the society, improved standards of living and a high level of educational expenses. However, considering that they are the two most important irreversible investments in everyone's life, it is highly likely that the level of uncertainty affects these decisions.

The decision to marry is highly irreversible in Japan because divorce is uncommon. An unmarried person has the option to marry, or a call option on the married life. In a highly uncertain labor market, in which future household income is uncertain, people have more possibility to experience an economic difficulty if married because higher costs are fixed until the future. Therefore, recent increase in uncertainty may be affecting people's decision to get married.

Having children is similar irreversible decision. If the future household income is uncertain, people have less confidence to have sufficient income to bring up their children. The value of option to wait (i.e. to have children), which is more valuable in such an uncertain situation, results in the lower birthrate. Although a statistical test has not been conducted, there is an interesting relationship between the total special birthrate and uncertainty measured by the standard deviation of return to the market. From 1980 to 1984, when the uncertainty was at quite low levels, total special birthrate slightly increased. Since 1985, uncertainty has significantly increased and birthrate decreased continually. These non-economic applications are not the main focus of this paper, but they might be very fruitful.

3. Overview of Basic Theories

Treatments of uncertainty

Traditional or neoclassical economic theories did not deal explicitly with risk or uncertainty until the development of the modern portfolio theory[9] and the Capital Asset Pricing Model[10]. Neoclassical theories did not have a good framework to treat risk until the modern finance theory was developed. The modern finance theory deals with the effects of risks on the demand schedule, and shows that only the systematic or undiversifiable portion of risks matters in equilibrium in the perfectly efficient market, and that the idiosyncratic or diversifiable portion of risks does not matter. In the financial markets, which are considered to be sufficiently efficient, each investor can diversify away the idiosyncratic risk and thus, does not require a premium for that portion. DCF or NPV method in capital budgeting also lies in this framework. The neoclassical theory, in summary, typically assumes that the systematic risk does not affect directly the supply schedule and that the total uncertainty does not affect the supply or demand schedule at all once systematic risks are accounted for.

Source of uncertainty

Investment is expenditure today in the hope of future income. However, almost all types of future cash flow are uncertain. While this is obviously true of stocks or real estate, even the fixed-income securities may be in danger of default. The US Treasury bond is probably a rare exception. Income uncertainty might result from either the broad market conditions or idiosyncratic events. In any case, few types of assets are free from income uncertainty.

It is true that the investment cost is less uncertain because the timing of expenditure is

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[9] See Markowitz (1952).

closer, but the cost is not certain at all, either. If the investment takes a relatively long period of time (such as in real estate development), the future cost is more uncertain than that of today. Even if the investment is once and for all, the cost is also uncertain if a highly volatile market affects it.

Even if the future cash flows are certain, we cannot escape from uncertainty because at least interest rates are uncertain. Ingersoll and Ross (1992) examine irreversible investment decisions when the interest rate evolves stochastically, and show that even those projects whose future cash flows are known with certainty have option value for waiting.[11] The paper shows that 1) an investment should be made only when the interest rate is sufficiently below the break-even rate of return, 2) the hurdle interest rate becomes more restrictive as the volatility of interest rates grows, and 3) a static decrease in expected interest rates for all future periods need not accelerate investment because such a change also lowers the cost of waiting. The result indicates that the volatility of interest rates may be more important than their level.

Reversibility and irreversibility

Capital investments such as real estate development are usually irreversible. Once a developer has paid the construction cost and obtained a built asset, the developer cannot reverse the decision or retrieve the money in exchange for the built asset. This irreversible characteristic makes capital investment analogous to the financial option. If an investment is reversible, the option to invest (i.e. option on the asset built in the future) is not valuable. For a reversible investment project, the investor will not wait but just invests because even if the situation turns

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[10] See Sharpe (1964), Lintner (1965) and Mossin (1966).

[11] They assume that the future cash flows are unaffected by interest rates and thus, assume that asset prices are inversely correlated with interest rates. This assumption might not be realistic in the real estate market although the

out to be bad later, the investor can get the money back and return to the original position. Therefore, even if the future is uncertain, if an investment opportunity is reversible, option to wait does not have value. Flexibility and irreversibility are two necessary conditions for real options to have value.

It should be noted that the investment option is irreversible even if the built asset can be sold later. Even if the investor can sell the developed asset to another party, the investor cannot reverse the development. Therefore, even the option to develop a generic building also has some option value. The specificity of the asset affects the option of the next level, that is, the option to change the use.

Difficulty in capital budgeting with the NPV rule

Decision making about irreversible investments under uncertain conditions is complicated task with the traditional capital budgeting methods. The traditional NPV rule usually implicitly ignores the option of investors to delay the investment and to make their decision after getting additional information. People sometimes forget that capital investments are not usually "now or never" decisions. Although the NPV rule suggests undertaking any positive NPV projects, it is possible that some projects should not be undertaken if compared with the plan to invest in the future, given that the investments cannot be revoked. Therefore, investors may make wrong decisions, even if they undertake positive NPV projects, because they are forgetting to compare the alternatives of investing in the future.

One way to avoid this mistake is to recognize that investors have more than one mutually exclusive alternative on different timings if investments can be delayed. Investors can

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results are theoretically valid.

choose when to invest although they cannot invest later again if they once invest. If investing later has a higher NPV than investing now, the investors should choose investing later even with the traditional NPV rule, because investors should choose the one with the largest NPV when they have to chose only one project. With this method, however, investors must consider an almost infinite number of alternatives for each project to decide the optimal timing of investment.

Therefore, it is quite effective to consider explicitly the value of option to delay a project when investors try to decide whether to invest or not. If investors explicitly consider the opportunity cost of killing such options, they can effectively determine the optimal timing of investment.

Real options theory

According to the real options theory, almost all types of investments are associated with real options. Real options in investments have been studied since the 1970's and well summarized in Dixit and Pindyck (1993) and Trigeorgis (1996) in their textbooks. Amram and Kulatilaka (1999) deal with real options in the context of corporate strategy. Here, I review some of real options in investments.

Investors who can choose the timing of an investment have the option to delay the investment (in other words, the option to wait for new information). Thus, land ownership can be seen as a call option on the asset that would be built on the land in the future (development option) because the landowner can choose the timing of development (Titman (1985)). With such options, investors can choose not to invest if they get bad news. Investment is equivalent to the exercise of the option to wait and thus, it has opportunity costs of killing such options.

Therefore, investors must consider explicitly these opportunity costs in order to make right investment decisions.

Sometimes, investments (i.e. exercise of an option) create new options. If the initial investment creates the opportunity to invest in the follow-on projects, the initial investment automatically creates the option on the cash flows from the follow-on projects. R&D can be seen as this type of option. R&D itself does not generate income, but it enables the firm to build a plant to utilize the results of the R&D. Phasing of the investment is another example. After the earlier phase, the investor can choose whether to proceed or not, depending on the prevailing market condition at the time. This right is a call option on the follow-on project. The underlying asset of real options can be varied, including a growth opportunity (growth option), an asset with an expanded capacity (option to expand), and an asset of other uses (option to switch use).

We can see such options differently as put option or option to default. For example, an investor who has the right to stop a phased project is equivalent to have committed the whole project with the option to stop or default in the middle of the process. The investor gives away the whole project in return for not investing further. Other put options include the option to reduce capacity of production to mitigate losses, the option to shut down the facility temporarily, and the option to abandon the facility forever.

Uncertainty and the other economic conditions change the value of these options, and thus, affect the investment decision by changing both the opportunity cost and the value of the investment. The more volatile the future cash flow becomes, the more valuable such options become. In such a case, both the opportunity cost of killing the option and the value of the newly created option increase. In other words, total volatility/uncertainty directly affects the supply schedule of built assets.

Policy implications

The real options theory provides several important policy implications. The most important is the effectiveness of typical monetary policy. Governments cut interest rates during recessions to stimulate investment. Lower interest rates are expected to stimulate investment by shifting asset demand upward. However, it is widely known that the interest rates can explain investment only weakly if tested econometrically. Japanese interest rates are currently close to zero, but investments are still decreasing. According to real-options theory, lower interest rates increase not only asset value but also the value of option to wait. Therefore, both effects offset each other and net effects on investment are ambiguous. In addition, real-options theory predicts that the uncertainty may be more significant than the level of interest rates. Thus, even if the interest rates are low, highly volatile market conditions may discourage investments. This is a quite reasonable hypothesis in the current Japanese economy. The results of the empirical tests of this paper support this hypothesis.

The policy implications of real options are not limited to monetary policy. More generally, too frequent policy changes such as reforms of tax system and subsidizing programs would make profitability of firms more uncertain and may have side effects on the investment decision. Although this uncertainty caused by public policy is normally overlooked, it may be quite important.

Implications for real estate

Real options theory is quite effective when analyzing the real estate market because the various options are naturally embedded in real estate. Option theory was first applied to real estate by Titman (1985). In the paper the vacant urban land is viewed as an option to purchase one of a number of different possible buildings at exercise prices that are equal to their respective construction costs. The paper applies option valuation methods developed by Black and Scholes (1973) and Merton (1973) and shows that the vacant land becomes more valuable as uncertainty about future prices increases. Williams (1991) constructs a model of real estate development as an option, in which both the optimal timing and scale of development is analyzed. Capozza and Sick (1991) discuss the value of redevelopment option. They show that the discount of leased properties from fee-simple properties, which cannot be explained with simple NPV models, can be explained largely by the option to upgrade or redevelop.

The value of land use flexibility and land use choice are also analyzed using option-pricing theory. Capozza and Helsley (1990) show that uncertainty (1) delays the conversion of land from agricultural to urban use, (2) imparts an option value to agricultural land, (3) causes land at the boundary to sell for more than its opportunity cost in other uses, and (4) reduces equilibrium city size. Childs, Riddiough and Triantis (1995) consider how the potential for mixing uses and for redevelopment impact property value, and show that operating flexibility increases property value and also affects the timing of initial land development. Geltner, Riddiough and Stojanovic (1996) consider the effect of land use choice on speculative land value and on development timing, and show that land use choice or multiple-use zoning may add over 40% to land value under typical economic circumstances.

Aggregate behaviors of real estate markets are also analyzed with real options theory. Real estate markets are notorious for their behavior of big booms and busts. An orthodox explanation of such behavior is provided by DiPasquale and Wheaton (1996) and Wheaton (1999) using stock-flow models, which do not account for uncertainty. According to them, the major causes of long and big cycles are 1) backward-looking expectations, 2) long construction lags, 3) the durability of real estate and 4) relative elasticity of supply. Other studies explain the cyclicality by the agency problem in non-recourse financing. With non-recourse financing, developers would lose nothing even in the case of overbuilding. Thus, developers continue construction as long as they get financing.

Alternatively, Williams (1993) considers the aggregate effects of the exercise of development options on demand and derives an equilibrium set of exercise strategies for real estate developers. The paper focuses on four distinguishing characteristics of real assets, that is, 1) demand for the good or service produced by a real asset has a finite elasticity, 2) developers have finite capacities, 3) the supply of options can be limited, and 4) developers can be less than perfectly competitive. This shows that all developers, in the equilibrium, build at the maximum feasible rate whenever income rises above a critical value. Grenadier (1995a) shows that the increase in any of the following —construction time, adjustment cost of changing occupancy rates or demand volatility— will lead to overbuilding. This paper also examines hysteresis in vacancy rates on the fully developed rental property. Grenadier (1996) goes a step further and provides a rational foundation of overbuilding in real estate markets using game-theoretic approach in an equilibrium framework. The paper analyzes the equilibrium exercise strategies of development options in both duopoly market and competitive market. It demonstrates that, in the case of symmetric duopoly, either simultaneous or sequential exercise of development options may take place depending on the initial conditions and parameter values. And it argues that the simultaneous exercises (building booms) following a downturn in demand may be the result of rational fear of preemption rather than of irrational overbuilding. Riddiough (1997) examines incentive and valuation effects of debt financing on land investment, focusing on a development option on the land and a default option on the debt that the landowner usually holds. The paper shows that a higher debt level may lead to delay in investment or underinvestment. Wang and Zhou (1999) allow a stochastic process in construction costs in their model and derive the optimal exercise strategies under various settings.

Empirical studies

Unlike rich theoretical works on real options, empirical studies have been less conducted. Some of the empirical studies to be noted are Pindyck and Solimano (1993), Quigg (1993), Holland, Ott and Riddiough (1999) and Moel and Tufano (1999). Although the number and area of empirical studies are insufficient, each study shows significant support to the option-based investment model.

Pindyck and Solimano (1993) conducted an empirical study using aggregate data of 29 countries. Their study also suggests that the volatility of the marginal profitability of capital — a summary measure of uncertainty — affects investment as the option-based theory suggests, but the size of the effect is moderate, and is greatest for developing countries. Quigg (1993) examines the empirical predictions of a real option-pricing model using a large sample of urban land transaction data. The paper concludes that market prices reflect a premium for the development option and that the option model has explanatory power for predicting transaction prices. Holland, Ott and Riddiough (1999) have examined the validity of option-based method using aggregate real estate data in the United States. Their study generally favors predictions of the option-based model, and hence suggests that irreversibility and delay are important considerations to investors. Regarding individual companies' decision-making, Moel and Tufano (1999) use the data of 285 gold mines and confirm many of the predictions from real options models. Specifically, they show that closures of mines are influenced by the price and volatility of gold, firms' operating costs, proxies foreclosing costs, and the size of reserves. It also shows strong evidence of hysteresis.

In the next section, I will specify a structural model based on Holland, Ott and Riddiough (1999) in order to test the effect of uncertainty in an equilibrium setting.

4. Model Specification

In this paper I use an equilibrium model to describe the commercial real estate asset market because it is necessary in the real estate market to incorporate the effect of new investment on asset demand. In efficient and competitive markets, the demand curve is perfectly elastic and price can be set exogenously. However, the real estate market is considered to be less efficient[12] because of high transaction costs, capital constraints, information frictions, long-term leases and construction lags. The commercial real estate market is less competitive, too, because each development project is fairly large and accounts for a significant part of the whole supply. Although the early studies of real options dealt with partial equilibrium and set asset price exogenously, recent studies typically use equilibrium models to incorporate the interactions between supply and demand. In such models, the demand curve is not limited to an extreme case (e.g. demand elasticity is infinite).

The model used in this thesis is basically the same as the one used in Holland, Ott and Riddiough (1999), although the data specification is different.

$$P_t = f_D\,(C, R, r, g, \sigma_{P,M}, \sigma) \qquad (1)$$

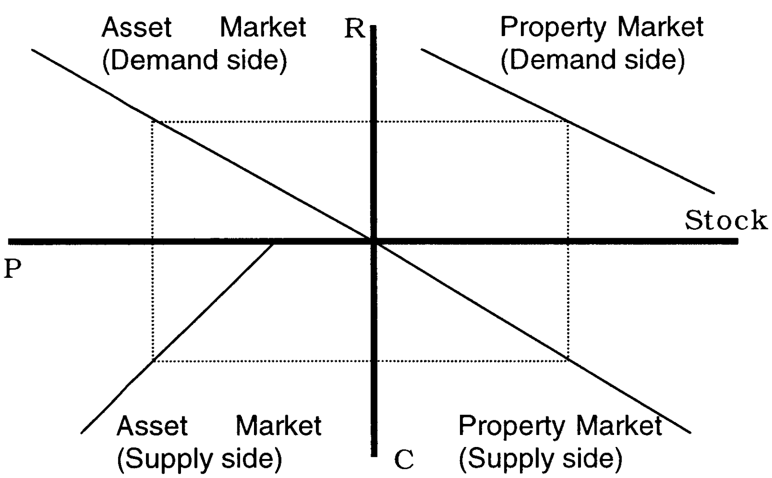
$$C_t = f_S\,(P, K, r, g, \sigma_{P,M}, \sigma) \qquad (2)$$

where P_t is asset price as of time t, C_t is new investment as of time t, R is expected rents, r is risk-free rate of interest, g is expected growth rate in rents, $\sigma_{P,M}$ is systematic risk of real estate, σ is total uncertainty of real estate return, and K is construction cost .

[12] Some blame backward looking expectations of developers as a large source of inefficiency in real estate markets although it is not clear whether such expectations are special in real estate markets.

Equation (1) expresses the demand of built assets. P_t, the willingness to pay for built assets by investors, is considered to be determined by C, R, r, g, $\sigma_{P,M}$, and σ. In this equation I include σ as well as other traditional factors because redevelopment option and abandonment option, the value of which is determined by total uncertainty, may affect the demand schedule. I also include new investment (C) in the demand equation in order to incorporate the effects of new investment on asset demand in real estate markets as mentioned above. This equation represents the demand side of asset market (the second quadrant in Figure 1), which is illustrated in the four-quadrant market model by DiPasquale and Wheaton (1996)[13].

Figure 1



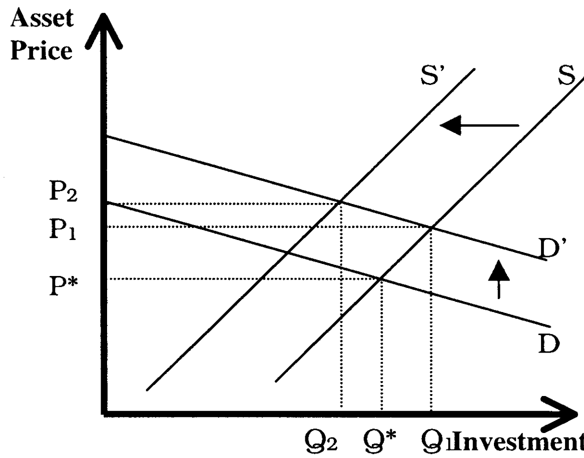
Equation (2) represents the supply side of real estate (the third quadrant in Figure 1). I include some independent variables that are normally omitted in neoclassical models, based on the option-based investment model. Even from those variables normally used in neoclassical investment models, somewhat different effects on investments are expected.

First, I include σ, or total uncertainty in return, in this equation because the value of option to wait is considered to affect the supply schedule. Greater σ should shift the supply schedule leftward (S→S' in Figure 2) at least in the short run because option to wait becomes

[13] Although this four-quadrant model is a static one, which deals with long-run equilibrium while this paper deals with rather short-term dynamic behavior, this four-quadrant model provides a good overall picture of real estate

more valuable. Neoclassical investment models take risks into account only by the systematic portion and only through the demand side. The idiosyncratic portion is ignored because it is diversifiable and thus does not alter the risk premium and the demand schedule. However, the option-based model predicts that greater total uncertainty would shift 1) the demand schedule upward (D →D') because the abandonment option or the redevelopment option becomes more valuable and 2) the supply schedule to the left (S→S') because more developers would decide to delay new investment.

Figure 2: Effects on asset markets of
1) A greater total uncertainty
2) A smaller systematic risk
3) A lower interest rate
4) A higher expected growth rate



Second, $\sigma_{P,M}$, or systematic risk itself, may play a role somewhat different from the role in the neoclassical framework. A smaller systematic risk (i.e. a smaller risk premium and a lower discount rate) makes the future cash flows relatively more valuable. It not only increases the asset value but also changes the value of various kinds of options. The value increases in the redevelopment option on the demand side and the option to wait on the supply side but decreases in the abandonment option on the demand side. Thus, a smaller systematic risk not only shifts the demand curve upward (D→D')[14], but also shifts the supply curve leftward

markets. This paper primarily focuses on the asset market, which is the left side of the figure.

[14] Here, I assume that the increase in the asset value is more than the decrease in the value of abandonment option. Thus, the demand schedule eventually shifts upwards.

(S→S') because of the increased value of option to wait on the supply side.

Third, r, or the level of interest rate (i.e. risk free rate of interest) may have an effect on investment similar to that caused by systematic risk. A lower interest rate, ceteris paribus, also results in a lower discount rate and shifts the demand upward (D→D')[13]. Therefore a lower interest rate is normally (i.e. in the neoclassical models) expected to stimulate investment. However, option-based investment models predict some offsetting effects in terms of quantity, that is, a lower interest rate may shift the supply schedule to the left (S→S') by increasing the value of option to wait, and thus may even reduce the quantity supplied.

Last, g, the expected growth rate on rents, is normally considered to change the demand by changing capitalization rate. A higher growth expectation, ceteris paribus, leads to a higher asset price and more investment. The option-based models predict that the expected growth rate on rents also changes the supply schedule by altering the opportunity cost to wait. A higher growth in the future rents makes foregone cash flows while waiting (i.e. opportunity cost to wait) relatively less important. Therefore, a higher expected growth rate may lead to waiting and reduce new investment (shift the supply schedule to the left) in the short run.

The effects of each independent variable on the supply schedule are summarized in Table 1. The clearest difference between the two models is the effect of total uncertainty. While the neoclassical model predicts no effect on supply, the option-based model predicts a negative effect[15].

[15] It should be noted that, according to the option-based model, the net effects on the equilibrium level of investments are ambiguous because both supply and demand shift.

Table 1: Effects of independent variables on supply (C)

	Neoclassical model	Option-based model
Total Uncertainty	$\frac{\partial C}{\partial \sigma} = 0$	$\frac{\partial C}{\partial \sigma} < 0$
Systematic risk	$\frac{\partial C}{\partial \sigma_{P,M}} = 0$	$\frac{\partial C}{\partial \sigma_{P,M}} > 0$
Interest rate	$\frac{\partial C}{\partial r} = 0$	$\frac{\partial C}{\partial r} > 0$
Growth rate	$\frac{\partial C}{\partial g} = 0$	$\frac{\partial C}{\partial g} < 0$

5. Data Specification

Data description

I use time series data and run three regressions to test the parameters in the model. The data are obtained from the Japan Development Bank, Ministry of Construction, Tokyo Stock Exchange, Data Stream, Economic Planning Agency, National Land Agency, Ikoma Data Service Systems and Sumitomo Trust Bank. The first regression is conducted using a long series of quarterly data from 1974 to 1998 (I refer to this as the Long Series in this paper). As shown in Appendix, this period includes four expansions and five recessions of the Japanese economy. The results of the Long Series are quite credible since the data are not limited in a special period. For the second and the third regression I use more recent monthly data of relatively short periods in order to examine in detail the recent investment decision. The second regression is from 1982 to 1998 (I refer to this as Short Series 1) and the third regression is from 1986 to 1998 (Short Series 2). Both of these periods correspond to a highly volatile period after the globalization of the Tokyo financial market. The data that are used as the variables in equation (1) and (2) are as follows.

1. Construction / Investment (C): For the Long Series, I use the log of capital investment value measured by million yen in real terms. The data is obtained from the Economic Planning Agency. For Short Series 1, I use the log of Private Building Construction Started measured by thousand square meters (Ministry of Construction), and for Short Series 2, the log of Integrated Statistics on Construction Work measured by million yen in nominal terms (Ministry of Construction). The choice of whether to use real or nominal series for all other variables depends on whether the investment data are in real or nominal terms. Therefore, the Long Series and Short Series 1 are expressed in real terms and Short Series 2 is

expressed in nominal terms. The real series are generated by deflating the nominal series by GDP deflator. Judging from relatively low inflation rates in Japan, especially during the period of Short Series 2[16], the choice would not affect the results significantly. In each series, I use the data of private non-dwelling construction or commercial real estate because the housing market is driven by demographic and life-style changes rather than by profitability. In addition, the housing market in Japan is highly affected by the government through public financing and direct supply by the public sector.

2. Price of real estate (P): Price is proxied by the log of the stock price index for the real estate industry provided by the Tokyo Stock Exchange. Japanese real estate companies usually hold real estate assets perpetually. Therefore, it seems reasonable to suppose that the stock price index of real estate companies represents the real asset value held by the companies. The validity of the use of the stock price is also confirmed by Quan and Titman (1999). They show that the contemporaneous relation between yearly real estate price changes and stock returns is quite high (0.84) and statistically significant in Japan[17].
3. Expected rent (R): Expected rent is proxied by the log of the periodic rent indicator realized one period hence. The periodic rent indicator is calculated by multiplying the estimated real estate prices by the cap rate. I use as the cap rate the income yield of MTB-IKOMA Real Estate Investment Index. I linearly extrapolate the annual cap rate of the index to generate quarterly and monthly data[18].
4. The cost of construction (K): I use the Construction Cost Deflators of Integrated Non-

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[16] Inflation rates between 1986 and 1998 are less than 3%.

[17] Their paper examines the correlation between real estate price and the price of market portfolio. Although the comparison does not directly apply to my paper, it is fair to say that the stock price of real estate industry has higher correlation with real estate price than market portfolio.

[18] I assume that the cap rate is relatively sticky, which would be valid judging from the data in the US. In fact, the

dwelling obtained from the Ministry of Construction.

5. Risk-free rate of interest (r): I use the simple yields on Japanese Government Bonds (8-10 years) listed on the Tokyo Stock Exchange selected with longest remaining maturity. The data are obtained from Datastream.

6. Expected growth rates (g): I use lagged values of the real GDP growth rates as a proxy of expected growth rates. The current values cannot be used because of the endogeneity problems. Construction or real estate investment is a part of GDP and thus, current GDP cannot be used as exogenous variables.

7. Systematic risk ($\sigma_{P,M}$): Systematic risk is proxied by the covariance of returns to commercial real estate and returns to the market. I assume that the daily returns to real estate and to the market are represented by the daily changes of the log of real estate stock price index and of TOPIX, respectively. Both real estate stock price index and TOPIX are provided by the Tokyo Stock Exchange. For the Long Series, I take covariance of these data for 90 trading days previous to the end of each period, and previous 25 trading days for Short Series 1 and 2[19].

8. Total uncertainty (σ): Total uncertainty is proxied by the standard deviation of returns to commercial real estate. I take daily differences of the log of real estate stock price index as daily returns to commercial real estate. I use the same method as used for the covariance; that is, I take standard deviation of 90 trading days previous to the end of each period for the Long Series, and previous 25 trading days for the two Short Series.

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income yields of MTB-IKOMA Index, which is currently the best to be obtained in Japan, change smoothly over time rather than stochastically. However, the rent indicator moves stochastically by the price change.

[19] The period to take covariance and standard deviation is determined so that the overlaps are minimized without

Preliminary qualitative examination of the data

Figure 3 shows the relationships between investments and total uncertainty from 1974 using the Long Series, and Figure 4 shows the recent relationships. Although formal statistical tests are not yet conducted, some notable strong relationships should be recognized. First of all, from the late 70's to the early 80's, Japan experienced a long-term decrease in uncertainty. In the same period, investments gradually increased.

Second, in both uncertainty and investments during the same period, there seem to be medium-term cycles, each of which extends about two years. In addition, it seems that investments move in the opposite direction to uncertainty lagging about one year. Considering that it typically takes one or two years since the planning phase until investments in real estate development, it seems reasonable to suppose that the effects of uncertainty on investments have one- or two-year lags. It is not reasonable for real estate development to suppose that the current uncertainty affects the current investment because the construction schedule cannot be easily changed once the development plan is approved and construction is contracted. This medium-term relationship continues until the 90's.

Third, since the mid-90's, both the cycles and lags has become shorter than before. Figure 4 shows the recent relationship in detail. After 1997, there is also a strong inverse relationship between investment and uncertainty. However, the cycles are about one year and lags seem about two to four months.

The results of more rigorous statistical tests are explained in Section 6.

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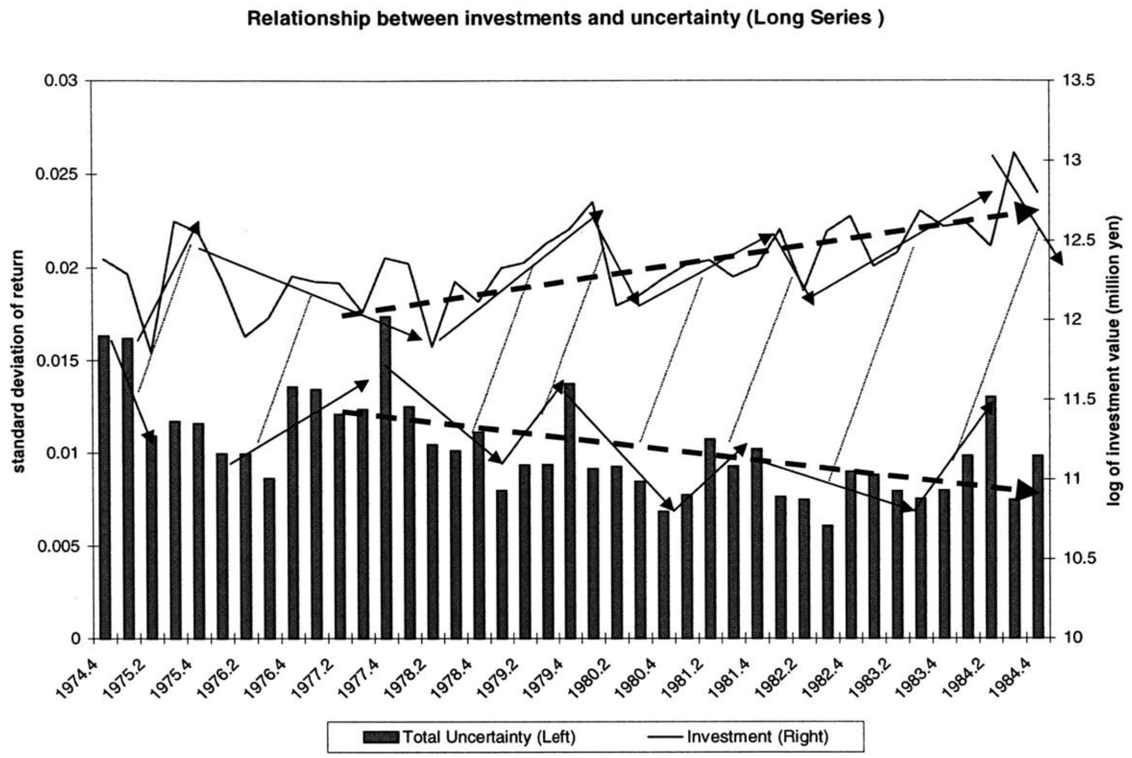
wasting data.

Figure 3


Relationship between investments and uncertainty (Long Series)
standard deviation of return
log of investment value (million yen)
0.03
0.025
0.02
0.015
0.01
0.005
0
13.5
13
12.5
12
11.5
11
10.5
10
1974.4
1975.2
1975.4
1976.2
1976.4
1977.2
1977.4
1978.2
1978.4
1979.2
1979.4
1980.2
1980.4
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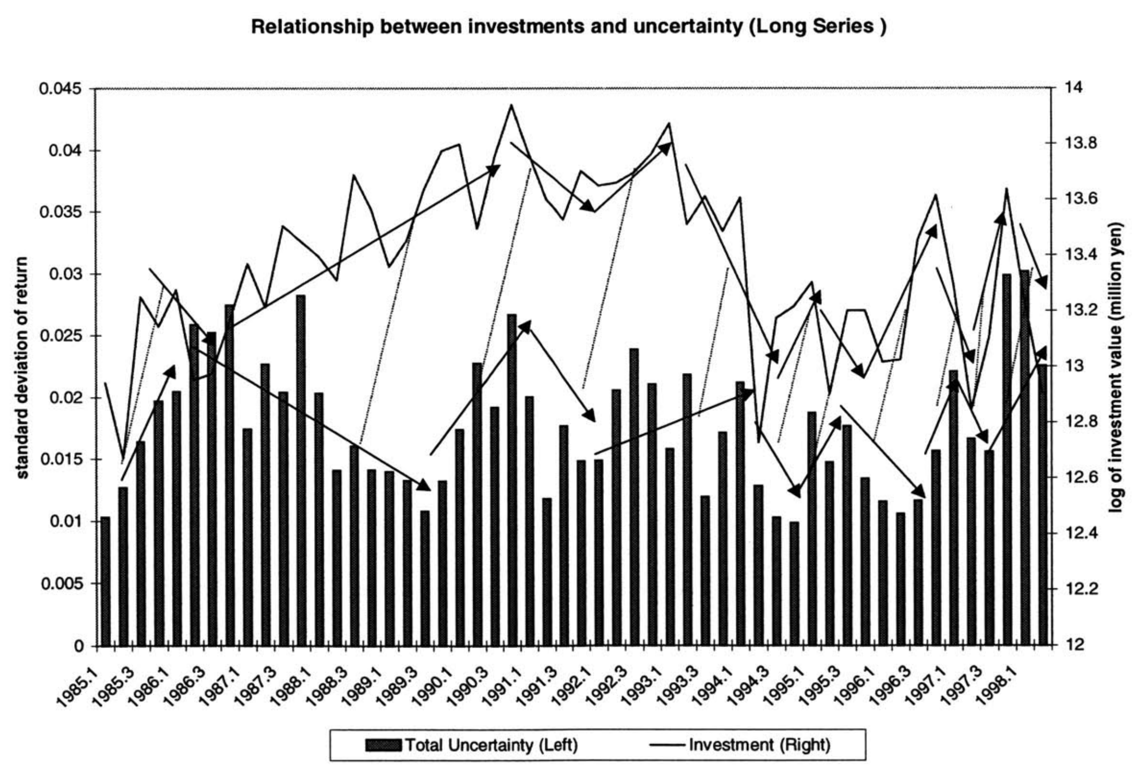
Total Uncertainty (Left)
Investment (Right)


Relationship between investments and uncertainty (Long Series)
standard deviation of return
log of investment value (million yen)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
14
13.8
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
12
1985.1
1985.3
1986.1
1986.3
1987.1
1987.3
1988.1
1988.3
1989.1
1989.3
1990.1
1990.3
1991.1
1991.3
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1993.1
1993.3
1994.1
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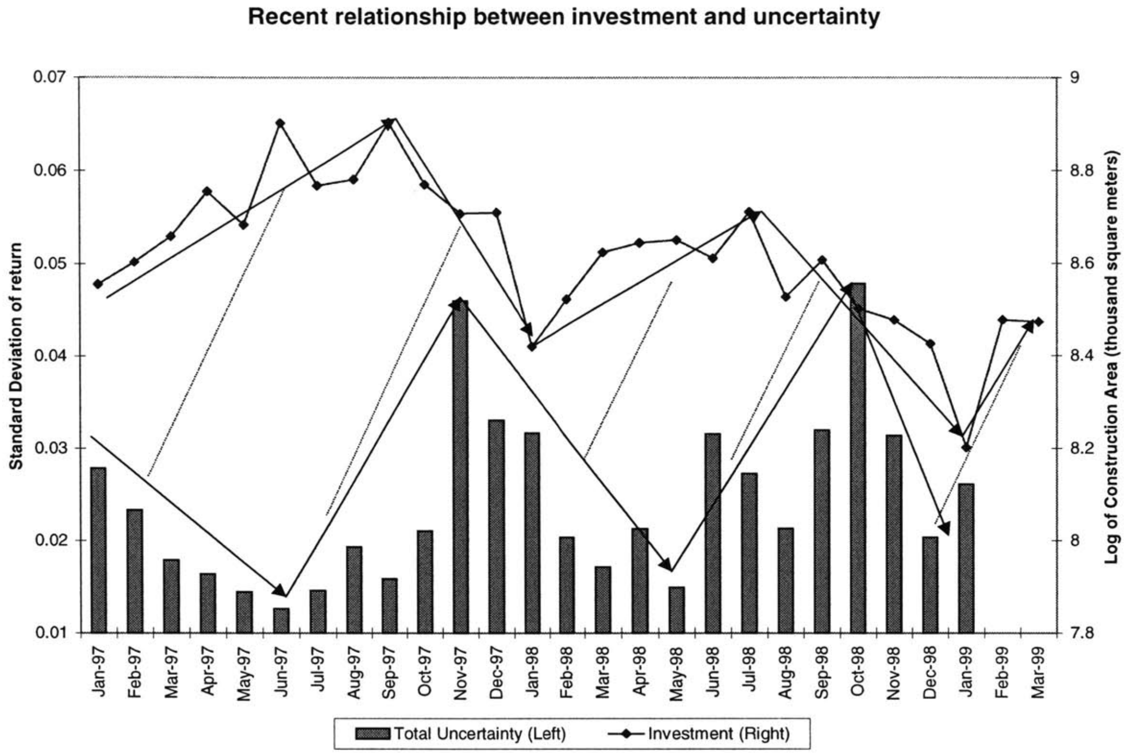
1998.1
Total Uncertainty (Left)
Investment (Right)

Figure 4



Quantitative examination of the data

Here I examine the stationarity and co-integration of the data so that the appropriate OLS estimators can be obtained. First, each series is examined for nonstationarity using Augmented Dickey-Fuller (ADF) test (see Dickey and Fuller (1979 and 1981)). I fail to reject nonstationarity for asset prices (P), investment (C), construction cost (K), rent (R), risk-free rate of interest (r), systematic risk ($\sigma_{P,M}$), total uncertainty (σ). Therefore, I assume that these series are nonstationary. On the other hand, I can reject nonstationarity only for expected growth rate (g) and thus, I assume that this series is stationary.

Next, I examine co-integration among nonstationary series using Engle and Granger's (1987) method in order to examine whether the variables can be directly used in regressions. I do not find any evidence of co-integration among the series. Therefore, the error term in any regression with C is likely to be nonstationary, and the estimated parameters may be biased and inconsistent. In order to make the error term stationary, I use the first differences of all of the nonstationary series. Also, in order to keep consistency, I take the first differences of expected growth rate, which is already stationary. Details of the examination above are explained in Pindyck and Rubinfeld (1998), Chapter 16. I used Eviews 3 for the tests in this paper.

Re-specification of the model

Based on the examinations above, I specify a linear model of asset market equilibrium as follows:

$$\mathbf{\Delta P_t} = \alpha_0 + \alpha_1 \mathbf{\Delta C} + \alpha_2 \mathbf{\Delta R} + \alpha_3 \mathbf{\Delta r} + \alpha_4 \mathbf{\Delta g} + \alpha_5 \mathbf{\Delta \sigma_{P,M}} + \alpha_6 \mathbf{\Delta \sigma} + \Delta\varepsilon_P \quad (3)$$

$$\mathbf{\Delta C_t} = \beta_0 + \beta_1 \mathbf{\Delta P} + \beta_2 \mathbf{\Delta K} + \beta_3 \mathbf{\Delta r} + \beta_4 \mathbf{\Delta g} + \beta_5 \mathbf{\Delta \sigma_{P,M}} + \beta_6 \mathbf{\Delta \sigma} + \Delta\varepsilon_C \quad (4)$$

where $\Delta\varepsilon_P$ and $\Delta\varepsilon_C$ are assumed to have independent normal distributions.

I include not only current values but also lagged values of all the independent variables except for Δg and ΔR. The current and lagged values for ΔP, ΔK, Δr, $\Delta\sigma_{P,M}$ and $\Delta\sigma$ are included because lagged values of independent variables are considered to affect the current dependent variable. The preliminary qualitative examination of data shows the possibility of lags up to two years. The long construction periods are an important characteristic of real estate development, and it is quite usual that an investment was decided more than a year before. The specific method to determine the lags to include is as follows:

First, lags are included continually up to the point where the last addition improves adjusted-R^2, with the maximum lag of 2 years (i.e. 7 lags for the Long Series and 23 lags for Short Series). For example, the 7th lag is included only if adjusted-R^2 is improved by including the 7th lag in addition to the current and lagged values from the first to the 6th. Once the highest adjusted-R^2 is achieved using the continuous lags, each of the variables is examined to find whether it improves the adjusted-R^2 or not. A variable is removed if the removal of it improves the adjusted-R^2. Therefore, only the variables that satisfy the adjusted-R^2 are included in the final model.

For Δg, lagged values are included but the current one is not because of the endogeneity problem mentioned in the data description. For ΔR, not only are the current and lagged values included, but also one period forward realized rent is included, because the current price is determined by the expected future rents if investors are forward looking.

As a result of this method, some of the independent variables may be excluded in the final model. Now, the model can be specified as follows:

$$\mathbf{\Delta P_t} = \alpha_0 + \alpha_1 \mathbf{\Sigma\Delta C} + \alpha_2 \mathbf{\Sigma\Delta R} + \alpha_3 \mathbf{\Sigma\Delta r} + \alpha_4 \mathbf{\Sigma\Delta g} + \alpha_5 \mathbf{\Sigma\Delta\sigma_{P,M}} + \alpha_6 \mathbf{\Sigma\Delta\sigma} + \Delta\varepsilon_P \quad (3)$$

$$\mathbf{\Delta C_t} = \beta_0 + \beta_1 \mathbf{\Sigma\Delta P} + \beta_2 \mathbf{\Sigma\Delta K} + \beta_3 \mathbf{\Sigma\Delta r} + \beta_4 \mathbf{\Sigma\Delta g} + \beta_5 \mathbf{\Sigma\Delta\sigma_{P,M}} + \beta_6 \mathbf{\Sigma\Delta\sigma} + \Delta\varepsilon_C \quad (4)$$

where Σ denotes the sum of the forward, current and lagged values as explained above. It should be noted that some variables might not appear in the final result of regression because of the lack of significance in explaining the dependent variable. Seasonal dummies are also included to account for the strong seasonality of investment variables.

To estimate the parameters, Two Stage Least Square procedure is employed.

6. Results and Discussion

The estimated parameters on the supply equation and the signs of parameters predicted by the option-based model are shown in Table 2.

Table 2: Estimates of the Structural Supply Equation

	Predicted signs	Long Series 1974:4-1998:2	Short Series 1 1982:4-1998:11	Short Series 2 1986:2-1998:11
β_0 (Constant)		----	----	-1.95×10^{-2} (3.39×10^{-3})
β_1 (for $\Sigma\Delta P$ (Asset Price))	+	4.03×10^{-1} (2.50×10^{-1})	----	2.50×10^{-1} (8.32×10^{-2})
β_2 (for $\Sigma\Delta K$ (Construction Cost))	-	-4.80×10^{-3} (3.07×10^{-2})	-1.60×10^{-2} (1.50×10^{-2})	3.12×10^{-2} (1.06×10^{-2})
β_3 (for $\Sigma\Delta r$ (Risk-free Rate of Interest))	+	-3.25×10^{-1} (2.47)	-9.40×10^{-1} (1.80)	7.20×10^{-1} (5.19×10^{-1})
β_4 (for $\Sigma\Delta g$ (Expected Growth))	-	3.19 (3.43)	1.02×10 (2.19)	5.70 1.09
β_5 (for $\Sigma\Delta\sigma_{P,M}$ (Systematic Risk))	+	9.19×10^{2} (3.90×10^{2})	----	2.11×10^{1} 2.27×10^{1}
β_6 (for $\Sigma\Delta\sigma$ (Total Uncertainty))	-	-3.78×10^{1} (1.21×10^{1})	-4.71 (1.66)	-4.92×10^{-1} (5.24×10^{-1})
R^2		0.76	0.84	0.98
Adjusted- R2		0.67	0.79	0.98
S. E. of Regression		0.16	0.05	0.02
Durbin-Watson		2.10	2.00	1.95

The dependent variable is the change in the log of 1) capital investment value (million yen) for Long Series, 2) Private Building Construction Started (thousand square meters) for Short Series 1, and 3) Integrated Statistics on Construction Work (million yen) for Short Series 2. The coefficients of seasonal dummies are not shown. Coefficient standard errors are in parenthesis.

In order to examine the effect of uncertainty on the investment decision, I start with β_6, the parameter for total uncertainty (σ). In all series, the signs of parameters are negative, which is consistent with the real-options theory. Especially the results in the Long Series and Short Series 1 are statistically significant at the one-percent level. Even in Short Series 2, if only the lagged values of uncertainty, each of which is a statistically significant explanatory variable, are concerned, they negatively affect investments[20]. The results show that the increase in volatility of real estate return shifts the supply schedule of built assets to the left, that is, reduce new investments. This result strongly supports the validity of the option-based investment model because this effect is the heart of the model.

The sizes of parameters indicate that a one-standard-deviation increase in total uncertainty reduces investments by 19% on a quarterly basis and by 3% on a monthly basis. Therefore, if the standard deviation of daily return of the previous quarter increase by 1%, investments decrease by nearly 40% in a quarter. If considered with monthly intervals, a one-percent increase in the standard deviation of daily return reduces investments by about 5% in a month.

The lag structures between total uncertainty and investments are consistent with the preliminary qualitative examination of the data. In the Long Series, which deal with quarterly data, 1-, 2- and 4-quarter lags of total uncertainty are finally included in the model. 2- and 4-quarter lags are especially significant in explaining the current change in investments at the 5% and 1% level, respectively. In Short Series 1, 4- and 7-month lags are especially significant at the 1% level, and in Short Series 2, 2- and 4- month lags are especially significant at the 5% and 1% level, respectively.

[20] The reason why the sum of coefficients for total uncertainty is not statistically significant is that the sign of

This result is also consistent with the hypothesis that the lags are becoming shorter in recent years because the Short Series tend to show shorter lags than the Long Series. The reason for the shorter lags may be the current highly competitive business condition of the construction industry. The capacity of the construction industry exceeds the demand in the 1990's. There is less supply constraint in development and thus, developers can advance projects relatively quickly when the conditions become favorable. Even when the conditions turn worse, construction companies are flexible in order not to lose their businesses.

Systematic risk ($\sigma_{P,M}$) is expected by the option-based model to have a positive effect on investments while neoclassical theory predicts no effect on asset supply once asset prices are controlled[21]. The result of the Long Series indicates that the systematic risk has a significant positive effect on investments (i.e. on the supply schedule) at the 2% level. Short Series 2 also shows a positive sign but the result is not so significant. Although the data of the Short Series are not sufficient to support the option-based model, at least they are not inconsistent with neoclassical theory. Based on the coefficient from the Long Series, a one-standard-deviation increase in systematic risk stimulates investments by about 10% in a quarter, which is economically significant. It is confirmed that distinguishing total uncertainty and systematic risk is quite important.

Price (P) parameters show positive signs, which are considered with both the option-based model and the neoclassical model, although the statistical significance and sizes of coefficients are not so large. Short Series 2 supports this basic notion at the 1% level, and the Long Series marginally supports almost at the 10% level, but Short Series 1 does not provide

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coefficient for the current value is opposite to those for the lagged values.

[21] The net effect of systematic risk on equilibrium level of investment is ambiguous due to the shifts of both supply and demand.

enough support. A one-standard-deviation increase in asset prices increases investments by 6% in a quarter and 2% in a month, which is not as significant as the effects of total uncertainty.

In the neoclassical theory, price is considered the first determinant of investments. These results indicate that, at least in the short-run, price may not be a significant determinant. Another possibility is that the "recession-induced constructions" shown by Grenadier (1996) are mixed with the "normal" behavior explained with the neoclassical theory. Grenadier shows that the construction boom and price decline may occur almost simultaneously under certain conditions because it may be optimal to exercise development options in the face of recession in a duopolistic market. If this is the case, the weak result of price coefficient is not inconsistent with real-options theory.

Interest rates (r) do not seem to have any significant effect on investment. Coefficients are not significant in any series. This is not inconsistent with neoclassical theory, which predicts no effect of interest rates on the supply schedule, and it does not provide enough support on the real-options theory. Although weak, Short Series 2 shows a positive effect at the 20% level (i.e. slightly supportive to the option-based model).

The effect of construction cost (K) is somewhat puzzling. Both theories expect construction cost to have a negative effect on investment. Although the Long Series and Short Series 1 indicate negative effects, they are not statistically significant. The coefficient of Short Series 2 is statistically significant at the 1% level, but positive. This may be because Short Series 2 is expressed in nominal terms. As for the first difference of construction cost (ΔK) during the test period of Short Series 2, almost a half of the data are negative in real series while only a third are negative in nominal series. This large difference in signs is only seen in construction cost. Therefore, the coefficient of construction cost may be disturbed by inflation/deflation. Another possible cause of the weak result is the mismatch between the investment and construction cost. Somerville (1999) emphasizes the importance of quality control in construction cost series in estimating the supply schedule in order to avoid biases. To fully control the quality of the buildings, more detailed micro data are necessary.

Last, expected growth rate (g) offers an interesting result. All series show positive parameters although the option-based model predicts negative ones. Especially, the two Short Series give significant results well above the 1% level. In fact, this result is consistent with Holland, Ott and Riddiough (1999), whose method of estimation I use. According to them, lagged changes in GDP may be picking up transitory, as opposed to permanent, changes in expected cash flow. If this is the case, developers may see a temporary growth in cash flows and "rush in" their projects to capture the benefit of temporarily favorable economic conditions. To put it another way, it is considered that a temporary increase in growth decreases the value of option to wait, resulting in an increase in investment. The current Japanese market may be in the opposite state, in which temporarily decreased growth expectation encourages developers to wait for a while. Therefore, this result may not inconsistent with the option-based model.

It seems reasonable to conclude that the results of the examination strongly support the option-based investment model. It is confirmed that the total uncertainty has significant negative effects on aggregate investments with a considerable magnitude. The effects of other variables are also almost supportive to the option-based model. Although some parameters do not provide decisive evidence, most parameters significantly support the option-based model.

Extension

As an extension, I also estimate the demand equation using Two Stage Least Square method. The estimated parameters and the signs predicted by the option-based model are shown in Table 3.

The results on the demand side also strongly support the option-based investment model. The option-based model and the neoclassical model predict the same signs except for total uncertainty. The fact that the coefficients of total uncertainty are positive and statistically significant (at least at the 2% level) after controlling for systematic risk shows that the real estate asset market takes into account the value of real options embedded in built assets such as abandonment option and redevelopment option. The result clearly shows that not only systematic risk but also total uncertainty affects asset value if real options are embedded in the asset. The sizes of the coefficient indicate that a one-standard-deviation increase in total uncertainty raises the asset value by 12% on a quarterly basis and 7% on a monthly basis, which are economically quite important.

The parameters of systematic risk ($\sigma_{P,M}$) are also all significant at least at the 10% level. This result also supports the option-based model as well as the neoclassical model. The sizes of the coefficients indicate that a one-standard deviation increase in systematic risk reduces the asset value by 8% on a quarterly basis and from 2% to 5% on a monthly basis. It should be noted that the signs of parameters of systematic risk and total uncertainty are opposite. Therefore, even if systematic risk increases, the asset price may not decrease as much as the neoclassical theory predicts if total uncertainty also increases.

The parameters of expected rent (R), interest rates (r) and expected growth (g) are also significant and consistent with the predictions by both the option-based model and the neoclassical model. When the effects of interest rates on supply and demand are considered together, lower interest rates may have positive effects on investments as predicted by the neoclassical theory because demand is significantly affected by interest rates while supply is not affected much either by interest rates or by asset price.

The parameters of investment (C) do not show a clear relationship between asset price and the level of investments. Any lag is included based on the adjusted-R^2 criteria. In an inefficient market or in a market that is not perfectly competitive, investors are considered to take into account the level of the new asset supply. This contradictory result may be because the data sets for investments do not work enough as information variables. It is highly likely that the investors react before the actual construction starts using preceding information such as government approval and development plan. The fact that the only the current variables are finally included in the equations implies that the old information does not matter. I use the amount of actual construction or investments as C because the main focus of this paper is on the supply side. It is necessary to examine whether the investment variable really represents the information for investors when the demand equation is mainly considered.

Table 3: Estimates of the Structural Demand Equation

	Predicted signs	Long Series 1974:4-1998:2	Short Series 1 1982:4-1998:11	Short Series 2 1986:2-1998:11
α_0 (Constant)		2.32×10^{-2} (1.33×10^{-2})	-6.18×10^{-3} (5.37×10^{-3})	----
α_1 (for $\Sigma\Delta C$ (Investments))	-	-1.02×10^{-1} (9.08×10^{-2})	-9.23×10^{-2} (1.16×10^{-1})	1.77×10^{-1} (1.84×10^{-1})
α_2 (for $\Sigma\Delta R$ (Expected Rent))	+	1.03 (1.71×10^{-1})	9.10×10^{-1} (1.20×10^{-1})	9.13×10^{-1} (1.18×10^{-1})
α_3 (for $\Sigma\Delta r$ (Risk-free Rate of Interest))	-	----	-2.72 (1.18)	-8.50 (2.91)
α_4 (for $\Sigma\Delta g$ (Expected Growth))	+	2.76 (1.31)	----	2.76 (1.71)
α_5 (for $\Sigma\Delta\sigma_{P,M}$ (Systematic Risk))	-	-7.86×10^{2} (2.90×10^{2})	-2.54×10^{2} (1.35×10^{2})	-7.66×10^{1} (4.41×10^{1})
α_6 (for $\Sigma\Delta\sigma$ (Total Uncertainty))	+	2.43×10^{1} (7.40)	1.08×10^{1} (4.58)	8.65 (2.22)
R^2		0.75	0.63	0.74
Adjusted- R2		0.70	0.58	0.69
S. E. of Regression		0.08	0.06	0.05
Durbin-Watson		1.93	1.99	2.03

The dependent variable is the change in the log of stock price index for real estate industry obtained from the Tokyo Stock Exchange. The coefficients of seasonal dummies are not shown. Coefficient standard errors are in parenthesis.

Implications

The results obtained in this paper have important implications on macro-economy and public policy. First, the fact that real estate developers implicitly consider the option value to wait makes clear the puzzles presented in Section 1.

Why does the monetary policy of extremely low interest rates fail to stimulate investments? Although the low interest rates must have some stimulating effects on investments, the increased level of uncertainty and temporarily decreased growth expectation have overwhelming negative effects on investments through the increased value of option to wait[22]. Therefore, if it is necessary to stimulate investments, the government is strongly encouraged to stabilize the economy and society to reduce uncertainty.

Why do Japanese firms tend to ignore the traditional Discounted Cash Flow (DCF) model in their capital budgeting? Firms implicitly account for the value of real options and thus, they adjust the result of DCF analysis. However, due to the lack of quantification of those option values, it is difficult to distinguish the reasonable and unreasonable decisions. It must be quite effective for a better decision-making to consider explicitly the value of real options.

Why do new constructions of real estate tend to show booms and busts? Construction boom and bust are also predicted by real options theory[23]. The firms that (implicitly) consider the real options value tend to create big cycles. In the relatively inefficient and less competitive real estate asset market, a rational exercise policy on development option is sometimes "developing no later than others" in order to maximize profits or minimize losses. Therefore, seemingly irrational boom and bust may be in fact the result of a rational choice.

[22] The increased systematic risk has ambiguous effects on investments based on real-options theory since it shifts the supply curve rightward while shifting the demand curve downward.
[23] See Grenadier (1996) and Wang and Zhou (1999).

Why do investors hesitate to invest after bad economic conditions even if the conditions have recovered? In Japan, the empirical tests do not support Tobin's q strongly[24]. There does not seem to be a convincing explanation yet. However, real options theory also predicts this kind of hysteresis. Due to the opportunity cost to kill the option to wait, the expected return must be sufficiently high in order to start investments. This high required return results in seemingly unreasonable hesitancy even if the decisions are in fact rational. Therefore, the implicit consideration of option value may be attributed to this puzzle in Japan.

[24] See Asako et al. (1989)

7. Summary

This paper focuses on the underlying forces on the investment decision in the Japanese real estate market. I first review the real-options theory and then examine the validity of the option-based investment model as opposed to the neoclassical investment model in the decision-making about commercial real estate development, using aggregate real estate data from Japan. I particularly emphasize the effect of uncertainty because it is the central difference between the two models.

I specify a structural model in order to incorporate the interactions between supply and demand in the real estate asset market. This model does not limit the demand schedule to an extreme case of infinite elasticity. In an asset market, which is usually not efficient and not perfectly competitive, it is necessary to construct an equilibrium model to distinguish the effects on supply and demand.

In order to conduct detailed empirical tests for a long period of time, I set three data series. The Long Series uses quarterly data of 25 years and Short Series 1 and Short Series 2 uses monthly data of about 15 years. In the supply equation, I find strong evidence that supports the option-based investment model. Especially, total uncertainty has significant effects on the investment decision. A lag structure is also found in the effect of total uncertainty. The parameters for other variables such as systematic risk, asset price, construction cost, risk-free rate of interest and expected growth also generally favor the option-based model. In the demand equation, too, the results strongly support the option-based investment model.

It should be concluded from these results that the real options significantly affect real estate investments in Japan, and thus, various kinds of real options must be incorporated in investment and economic models for the use of business, academics or public policy.

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APPENDIX:

Summary of the Japanese economic history since the 1960's:

1965-74	The period of high growth (1965/10-70/7 Izanagi Economic Boom)
1969	The New Comprehensive National Development Plan
1969-74	Tight office space market (vacancy rates in Tokyo are less than 1%)
1971-1973	Nationwide Construction Boom
1973	The First Oil Crisis
1973	The second baby boom
1975	Low capacity utilization
1975-84	The period of stable growth (true in stock price)
1977	The Third Comprehensive National Development Plan
1980	The Second Oil Crisis
1981-89	Excess liquidity in money market (high growth in money supply (M2+CD))
1981-91	Large inflow of people into Tokyo
1983-	Active equity finance, globalization of Tokyo financial market
1984-91	Surge in demand for office space especially in Tokyo (vacancy rates are less than 0.4%)
1985/5	Plaza Agreement → Appreciation of yen
1986	BOJ startsto cut interest rates
1986-89	Surge in stock price (peaked on Dec 29, 1989)
1986/12-91/2	Heisei Economic Boom or "Bubble Economy"
1987	The Fourth Comprehensive National Development Plan →predicted the surge in the demand of office space
1988	Real GDP growth of 6% and land price appreciation of more than 20%
1989	BOJ starts to raise interest rates
1990	The stock market crashes. A peak of long-term interest rate
1991	Change in Land Price Tax and Property Sales Tax. Stabilized money supply. Crash of real estate markets and large decrease in GDP growth (peak = 1991/2)
1993	Low capacity utilization. Inflow of people into Tokyo stopped.
1994	Change in the tax base of Property Tax
1995-	Disinflation

- Expansion: 1965/10-1970/7
- Recession: 1970/8-1971/12
- Expansion: 1971/12-1973/11
- Recession: 1973/12-1975/3
- Expansion: 1975/4-1977/1
- Recession: 1977/2-1977/10
- Expansion: 1977/11-1980/2
- Recession: 1980/3-1983/2
- Expansion: 1983/3-1985/6
- Recession: 1985/7-1986/11
- Expansion: 1986/12-1991/2
- Recession: 1991/3-